

State of California
The Resources Agency
Department of Water Resources

South Delta Temporary Barriers Project

2005 South Delta Temporary Barriers Monitoring Report

December 2006

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Chapter 1. Introduction

The Department of Water Resources (DWR) issued the Draft Environmental Impact Report and Environmental Impact Statement for the South Delta Water Management Program in 1990.

Objectives of the program are to achieve the following:

1. Increase water levels, circulation patterns and water quality in the southern Delta area for local agricultural diversions.
2. Improve operational flexibility of the State Water Project to help reduce fishery impacts and improve fishery conditions.

Because of concerns related to both agriculture and the fisheries, the Temporary Barriers Project (TBP) was initiated to better determine effects of installing permanent barriers in the southern Delta. A five-year program began in 1991 to test a facsimile of the proposed barriers. In 1996, this test was extended for another five years. In 2001, DWR received an extension from the US Army Corp of Engineers to construct and operate the South Delta Temporary Barrier Project from 2001-2007. Because of varying hydrological conditions, and therefore varying hydrodynamic patterns, as well as concerns for endangered species, the number of barriers installed and the installation schedules have been different each year of the program. The barrier installation and removal dates are based on the US Army Corp of Engineers 404 Permit, the California Department of Fish and Game 1601 Permit and various Temporary Entry Permits required from landowners and local reclamation districts. Table 1-1 shows installation and removal dates for the various years of the Project.

Although the South Delta TBP has been in place since 1991, the Middle River barrier and the fall Head of Old River barrier have been installed in earlier years under different programs. The Grant Line Canal barrier was installed for the first time in 1996, at a site about 4.5 miles east of the originally proposed location. In 1997, the spring Head of Old River barrier was installed with two 48-inch culverts. In 1998, none of the barriers were installed due to high river flows throughout the spring and summer. In 1999, the Head of Old River barrier was not installed in the spring or the fall but the other barriers were installed. In 2000, 2003, 2004 and 2005, all the barriers were installed (see table at end of introduction) except for the Spring Head of Old River Barrier which was not installed in 2005 due to excessively high flows in the San Joaquin River (SJR).

Subsequent to the 2001 project extension, a new DWR Monitoring Plan was developed that specifically complies with the requirements of: 1) the April 4, 2001 California Department of Fish and Game (DFG) Incidental Take Permit No. 2081-2001-009-BD, 2) the March 29, 2001 DFG Streambed Alteration Agreement No. BD-2001-0001, 3) the April 5, 2001 National Marine Fisheries Service (now called NOAA Fisheries) Biological Opinion (BO), 4) the March 30, 2001 Fish and Wildlife Service BO for the Department of Water Resources Temporary Barriers Project 2001-2007.

The DWR Monitoring Plan consists of specific elements that are discussed in the following chapters. DWR participates in and /or funds these monitoring efforts. In some cases, funding may be augmented by Interagency Ecological Program (IEP) and /or CALFED funds. The elements of the monitoring plan came from permit conditions required by DFG, NOAA Fisheries, and USFWS. It covers fish species including salmon, steelhead, delta smelt and splittail. Also included are terrestrial species such as Swainson's hawks, pond turtles, and sensitive plants. The following are brief descriptions of each chapter.

Chapter 2. Fisheries Monitoring and Water Quality Analysis (Prepared by Tobi Rose, DFG)

In 2001, a pilot study was developed to provide an experimental approach to determining the behavioral response of fish with the installation of the temporary barriers in the south Delta, however, this project was cancelled due to insufficient data collection and recapture capabilities. A revised program was planned for 2003, however, funding and personnel shortages precluded implementation, therefore the fish monitoring study was not conducted in 2003, 2004, or 2005. Future studies are planned but implementation will be dependent on the availability of necessary staff.

Water quality analysis was conducted and physical water quality parameters were monitored not only for their possible effect on the fisheries but for other pertinent biological information, such as null zones.

Chapter 3. Kodiak Trawling in Old and San Joaquin Rivers (Prepared by Andy Rockriver, DFG)

Fish entrainment monitoring at the Spring Head of Old River Barrier (SHORB) was designed and implemented by the Department of Fish and Game (DFG) to evaluate and quantify fish entrainment with the following specific objectives:

- Determine the total number of juvenile Chinook salmon and other fish species entrained through the culverts at the HORB.
- Determine the percentage of coded-wire tagged (CWT) salmon released at Mossdale and Durham Ferry entrained into Old River.
- Determine tidal and diel effects on juvenile Chinook salmon entrainment.

The results are intended to provide information on the design and operation of a future permanent operable barrier at the head of Old River. In years 2004 and 2005 the SHORB was not installed due to high flows in the SJR, therefore Kodiak Trawls were conducted instead.

Chapter 4. Salmon Smolt Survival Investigations (Prepared by Patricia Brandes, USFWS)

This section describes the methods used in conducting the 2005 Vernalis Adaptive Management Plan (VAMP) Chinook salmon smolt survival investigations, and presents results of the calculated survival indices and absolute survival estimates for juvenile Chinook salmon during the VAMP 2005 test period.

Chapter 5. Barrier Effects on SWP and CVP Entrainment (Prepared by Jim Long, DWR)

This chapter discusses the effects the TBP has on fish entrainment at the Skinner (State Water Project) and Tracy (Central Valley Project) fish facilities. Daily salvage densities were analyzed and compared to TBP operations, Delta hydrodynamics, and project export flows.

Chapter 6. Swainson's Hawk Monitoring (Prepared by Mike Bradbury, DWR)

This section describes Swainson's hawk observations and the effects of the barriers construction activities on nesting pairs within ½ mile radius of the sites.

Chapter 7. Water Elevations (Prepared by Mike Abiouli, DWR)

Monitoring was conducted to determine the effects of the barriers on water surface elevations and circulations patterns in the southern Delta channels.

Chapter 8. Weekly Water Quality Sampling (Prepared by Shaun Philippart, DWR)

This monitoring was conducted to evaluate the changes in various water quality parameters due to installation and operation of the barriers. The water quality parameters measured included water temperature, dissolved oxygen, specific electrical conductivity, and turbidity. Water samples were also sent to an analytical laboratory for analysis of dissolved ammonia, dissolved nitrite and nitrate, dissolved organic nitrogen, dissolved orthophosphate, chlorophyll *a*, and pheophytin *a*.

Chapter 9. Hydrologic Modeling (Prepared by Bob Suits, DWR)

The DWR Delta Simulation Model, DSM2-Hydro, was used to conduct a hydrodynamic simulation of the effects the temporary barriers have on water levels in the south Delta for the year 2005. The DSM2-simulated stages and flows are then compared to historical data in the south Delta.

Chapter 2. Fisheries Monitoring and Water Quality Analysis

Introduction

The South Delta Temporary Barriers Project (TBP) began in 1991 and consists of the construction, operation, and monitoring of four temporary rock fill barriers. Three of the barriers, located in three south Delta channels (Grant Line Canal, Old and Middle rivers), are constructed seasonally and operate during the agricultural season, usually April through October. They are designed for two purposes: (1) the improvement of water levels and circulation patterns for agricultural users and (2) the collection of data for the design of permanent barriers. The fourth barrier, located at the head of Old River, is designed in the spring as a fish barrier to prevent fall-run San Joaquin River Chinook salmon smolts, as well as, Central Valley steelhead smolts from the San Joaquin River watershed from migrating down through Old River towards the Central Valley Project (CVP) and the State Water Project (SWP) export facilities. This barrier is also installed in the fall to increase water quality on the San Joaquin River downstream of the barrier. Of those four barriers, the Middle River barrier (MIDRB) near Victoria Canal has been installed since 1987; the Old River barrier (OLDRB) near Tracy pumping plant has been installed since 1991; the Grant Line Canal barrier (GLCB) near the Tracy Boulevard overpass has been installed since 1996; and the spring head of Old River barrier (HORB) was installed in 1992, 1994, 1996, 1997, and 2000-2004. In 1998, high flows in south Delta channels prevented the installation of all four temporary barriers, however, the monitoring program continued as planned.

Since 1992, a seasonal fish-sampling program has monitored the fishery resources and water quality in the project area. From 1996 through 2000, the fish monitoring program was changed from a year-round sampling study, that gathered only descriptive (qualitative) information, to a study conducted March through October concentrated on providing not only qualitative but quantitative measures of potential effects of the barriers on the various fish species inhabiting the channels. In 2001, a pilot study was developed to provide an experimental approach to determining the behavioral response of fish to the installation of the temporary barriers. However, this project was cancelled due to insufficient data collection and recapture capabilities.

Fisheries monitoring was not conducted from 2002 through 2005, however, physical water quality parameters were monitored not only for their possible affects on the fisheries but for other pertinent biological information, such as null zones. A null zone occurs when the upstream flow of water negates the downstream flow of water, creating an area with zero net flow and potentially poorer water quality for fisheries. The objectives of the 2005 study plan were:

- Determine water quality profiles of the channels affected by the temporary barriers.
- Determine if there are null zones within the south Delta, upstream of the three barriers.

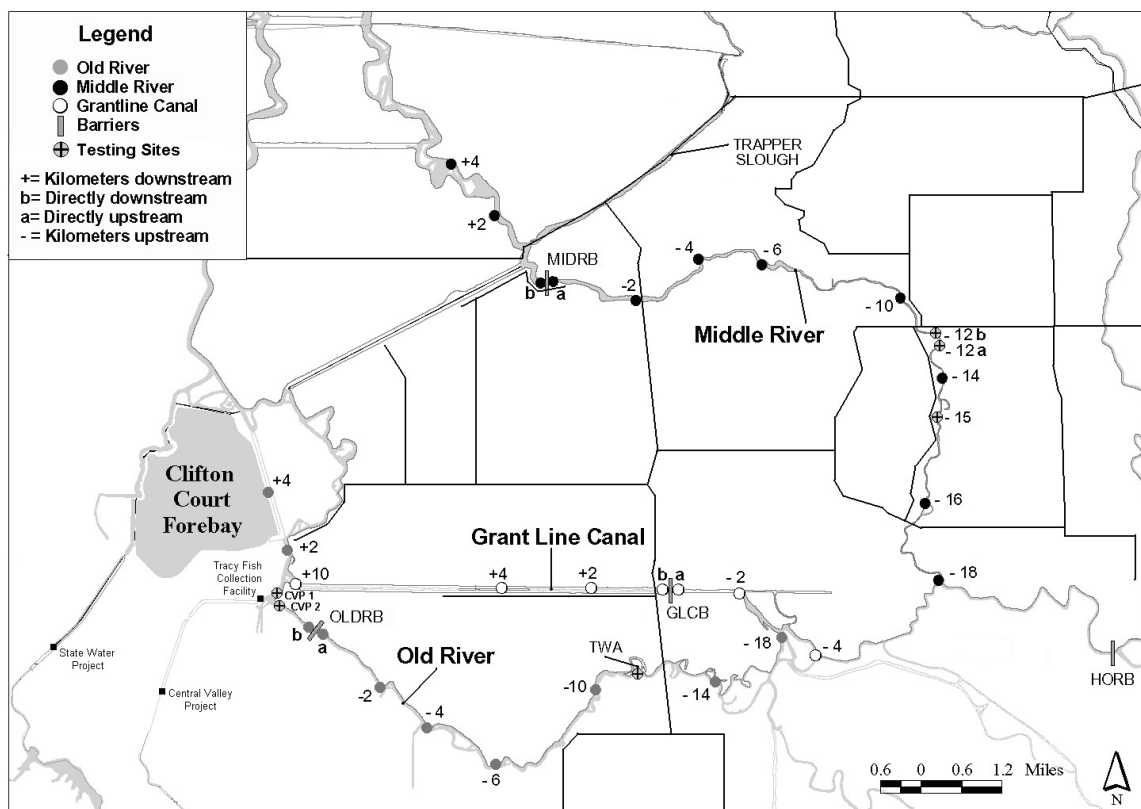
Materials and Methods

Twenty-eight permanent water quality sites were sampled on Grant Line Canal, Old and Middle rivers (Figure 2-1). A hydrolab was used to determine water temperature in °C, dissolved oxygen in mg/L, and specific conductance in $\mu\text{mhos/cm}$ (the water's ability to conduct an electric current and is directly related to the total dissolved salts or ions normalized to 25°C). Turbidity was measured in NTUs (the degree to which light is scattered by suspended particles) using a

portable turbidimeter. Two replicate water samples were collected at each site at depths equal to 40 and 60 percent of the total depth. Water samples were taken from downstream to upstream at the beginning of each tidal stage (ebb and flood tides). Tidal stage, location, and time were recorded at each permanent site. Monthly average air temperature was collected from the Tracy Pumping Plant station off of the Western Regional Climate Center Website (www.wrcc.dri.edu).

Each channel's water quality parameters were compared over time (months) and location (sampling sites). Three different water quality profiles were graphed for each channel and parameter: (1) the monthly average in relation to the barrier (Figures 2-2 through 2-5); (2) the yearly average in relation to the barrier (Figure 2-6); and (3) the monthly average (Figure 2-7). As in previous years, the data used for analysis this year was an average of the four samples taken at each location. Statistical analysis was not performed this year because of insufficient data collection due to various mechanical difficulties of equipment, other project requirements, and the growth of water hyacinth making navigation through the waterways impossible.

Figure 2-1. 2006 Water quality sampling sites in the south Delta



Results and Discussion

The water quality results from 2005 are similar to results from previous years. All three sets of graphs show similar trends. However, there were some differences and they are addressed in the following sections.

Specific Conductance (Figures 2-2, 2-6A, 2-7A)

In previous years, the specific conductance was higher upstream than downstream. This year, however, the specific conductance in all three channels was similar upstream and

downstream and significantly lower throughout the monitoring period. The 2005 specific conductance readings, in each of the channels, were the lowest since 2001 (Table 2-1). The greatest decrease in specific conductance occurred during the April - June time period in all three channels. Old River had the highest overall specific conductance and Middle River had the lowest. Grant Line Canal and Middle River showed similar patterns of specific conductance for each month in relation to the barrier. This trend in specific conductance may indicate a relationship between specific conductance and location. Old River also showed similar patterns in specific conductance except for the months of August through October when an increase was apparent starting directly downstream of the barrier.

The results indicate a possible relationship between specific conductance and location. Since specific conductance was relatively constant in all three channels. No null zones due to high spikes in specific conductance are apparent. Contributing factors for the low specific conductance from April through June in the south Delta may include: 1) the higher flows down the San Joaquin River due to the wet water year (Figure 2-9) could have helped disperse and move the water out of the system faster, 2) the Grant Line Canal barrier not being completed/closed until July 14th could have helped move the water out of the system faster, and 3) the quality of the water released at Vernalis may have been of better quality and helped disperse the specific conductance readings in the south Delta. Variances in the data may be caused by farming activities, such as agricultural diversion/return locations, amount of water used and returned, and the time of year it is used.

Dissolved Oxygen (Figures 2-3, 2-6B, 2-7B)

As in previous years, the 2005 dissolved oxygen values for Old and Middle rivers were initially elevated during the spring and then decreased throughout the summer months, before improving again in the fall. Grant Line Canal seemed to have a slight but steady decline in dissolved oxygen from spring to fall with a small increase in July. All three channels had similar monthly dissolved oxygen patterns that suggest a relationship between dissolved oxygen and the time of year. An important characteristic for all three channels is that at some point the dissolved oxygen fell below 5.0 mg/L, the minimum water quality objective stated in the California Regional Water Quality Control Board's Basin Plan (4th ed.). However, this was less common than in previous years and most monthly dissolved oxygen averages stayed above this critical point. Grant Line Canal had the highest overall dissolved oxygen readings and had no apparent sag below the barrier as seen in previous years. As with specific conductance, Old River showed consistent monthly dissolved oxygen readings between sites except for the months of August through October. During this time, a slight sag is apparent starting directly below the barrier. Middle River's dissolved oxygen sag was located approximately 4 to 6 km upstream of the MIDRB. However, this sag may be exaggerated due, in part, to the limited collection of data directly above to 6km upstream of the barrier from July through October.

Results suggest a possible relationship between dissolved oxygen and the time of year. Sags in dissolved oxygen in Old and Middle rivers could indicate areas where null zones are present (Figure 2-10). Variances in dissolved oxygen may be due to high flows from the San Joaquin River, water quality of the water from the San Joaquin River, water temperature, water hyacinth, water agitation, localized (agricultural) nutrient loading, and primary production.

Water Temperature (Figures 2-4, 2-6C, 2-7C)

2005 water temperatures are similar to previous years in that the profile for all three channels began low, then increased over the summer, and decreased in the fall. This trend is

opposite of the dissolved oxygen profile. All three channels show approximately identical monthly averages in water temperature that suggests a relationship between water temperature and the time of year. Grant Line Canal's average water temperature among sites was slightly lower than Old and Middle rivers which is not shown in previous years. Average monthly water temperatures in Grant Line Canal were lower than in Old and Middle Rivers from March through June. By July, water temperatures were similar among all three channels. Also, average monthly water temperatures in all three channels tracked well with the average monthly air temperature (Figure 2-8).

The results indicate a possible relationship between water temperature and the time of year. This means that the water temperature of all channels varies greatly month to month but varies insignificantly site to site. Water temperature seems to follow air temperature based on the graphical data. The lower water temperatures on Grant Line Canal may be due to higher inflows of water from the San Joaquin River than in previous years since a majority of that water flows down Grant Line Canal.

Turbidity (Figures 2-5, 2-6D, 2-7D)

As in previous years, the turbidity measurements of 2005 typically stayed well below 50 NTU's. Old and Middle rivers had increased turbidity upstream of the barriers while Grant Line Canal did not increase upstream of the barrier. Each channel showed similar patterns of turbidity for each month. This may indicate a relationship between turbidity and location. The spike located 14 km upstream of the MIDRB was not evident this year as it has been for the past three years. The spike located 6 km upstream of the MIDRB in August was due to a high reading taken in water hyacinth that had just been agitated by the outboard jet motor from the boat used for navigating the waterways.

These results indicate a possible relationship between turbidity and location. The varying turbidity might be due to various activities, such as agricultural diversion/return operations and locations, suspended solids from agricultural runoff, water recreation (water agitation), bottom feeders, etc.

In summary, the water quality in the south Delta appeared to be better in 2005 than in previous years with lower specific conductance and higher dissolved oxygen readings in all three channels. This could be the result of a wet water year. The higher flows down the San Joaquin River in 2005 may have helped improve water quality in the south Delta by increasing water flow through the south Delta channels. Also, considerable amount of water hyacinth on Middle River hindered the collection of data during a potentially crucial time of year (July through October) in a potentially critical area (directly below the barrier to 6 km upstream of the barrier). As a result, only one to two sets of data of this potentially lower quality water were collected. In contrast to Middle River, Old River did not have the water hyacinth setback which may have contributed to better water quality in that channel.

There is a possible relationship between the water quality parameters, dissolved oxygen and water temperature, and the time of year (months) and the water quality parameters, specific conductance and turbidity, and location (sampling sites). Potential null zones are present in Middle River and Old River due to sags in dissolved oxygen. No null zones, due to highpoints in specific conductance, are apparent for any of the three waterways. Old River's dissolved oxygen null zone is again oddly located directly downstream of the barrier. Water temperature seems to tracks the ambient air temperature and thus air temperature may have an indirect effect on dissolved oxygen levels (Figure 2-8). Finally, all the water quality parameters seem to be affected by similar activities such as agricultural diversion/return operations and locations, water agitation,

localized nutrient loading, suspended solids from agricultural runoff, primary production, algae blooms, erosion, bottom feeders, low flow, and a wet water year.

Efforts were made this year to pinpoint the cause/area of water quality concerns on Middle River (the spike in turbidity located 14 km upstream of the barrier) and on Old River (sag in dissolved oxygen located directly below the barrier). Three turbidity testing sites were added to Middle River (Figure 2-1) to help pinpoint any influences upstream or downstream of the area of concern. The turbidity spike that occurred on Middle River for the past 5 years, however, was not detected in 2005 and the water quality profile, with the testing sites included (Figure 2-11), indicated no highpoints in turbidity. To determine if dissolved oxygen was low upstream as well as downstream of the Tracy Fish Collection Facility (TFCT), two dissolved oxygen testing sites were added to Old River (Figure 2-1). The water quality profile, with the testing sites included (Figure 2-12), suggests dissolved oxygen decreases between the TFCT and the OLDRB. All testing sites included this year will be included in next years sampling season to help monitor these potentially poor water quality locations.

An important topic that needs to be discussed pertains to the aggressive growth of water hyacinth and how it negatively impacts water quality monitoring during the summer and fall. The growth of water hyacinth in Middle River was so extreme that by the end of July, the crew was often unable to complete the sampling because the boat could not traverse the waterways.

This year, we considered alternative plans for collecting the field data when the waterways were no longer navigable. The use of an airboat was considered, however, after much discussion it was decided that the water hyacinth would be too thick and tall for an airboat to navigate through. This left the last plan which was to access the sites via roads instead of by boat. Middle River was navigable by boat from the head to the sampling site 10 km upstream of the barrier where typically, a solid sheet of water hyacinth blocked further passage. We were still able to sample some of the sites between the barrier and 10 km upstream on the occasional high tide or by road. When accessing by road was necessary, we walked along levee roads or sampled at bridge crossings. The slower land access may have biased the results by affecting the time of day and tidal stage in which the data were collected. Also, some sites were not accessible which led to inconsistent data collection. A total of 13 samples should have been collected in the last 3 months of sampling on Middle River however none of these were able to be fully completed, one was cancelled due to equipment malfunction, and the other twelve were only partially completed. In 2005 water hyacinth multiplied so quickly that by mid-July Middle River was not navigable and stayed in that condition for the remainder of the year. In contrast to Middle River, Old River only had small outbreaks of water hyacinth in 2005. Old River remained navigable throughout the sampling season and the outbreaks did not impact water quality sampling.

Recommendations

A similar study is planned for 2006 to further evaluate effects of the temporary barriers on the south Delta water quality. Testing sites selected to monitor potential null zones/areas of concern in 2005 will remain a part of the water quality monitoring program in 2006. We may also add more sampling sites upstream of the Old and Middle rivers barriers so that all sites are approximately 2 km apart. Finally, other alternative sampling plans should be considered to deal with the water hyacinth problem. The ability to consistently collect water quality data at all sample sites throughout the summer and fall will improve our data analyses.

Table 2-1. Average monthly specific conductance from 2001 to present and the percent decrease in conductance between 2005 and the previous years

Channel	Month	Year									Channel Average
		2005	2004	2003	2002	2001	2004	2003	2002	2001	
		Average Specific Conductance (µmhos/cm)					Percent Decrease Compared to 2005				
Grant Line Canal	Mar	574	782	1250	936	788	27%	54%	39%	27%	48%
	Apr	279	651	860	841	828	57%	68%	67%	66%	
	May	151	635	621	503	659	76%	76%	70%	77%	
	Jun	176	769	503	746	733	77%	65%	76%	76%	
	Jul	418	693	677	764	824	40%	38%	45%	49%	
	Aug	509	776	735	801	911	34%	31%	37%	44%	
	Sep	538	804	735	814	866	33%	27%	34%	38%	
	Oct	589	869	652	672	873	32%	10%	12%	33%	
	Total	404	747	754	760	810	47%	46%	48%	51%	
Old River	Mar	555	705	904	899	646	21%	39%	38%	14%	37%
	Apr	365	593	691	871	615	38%	47%	58%	41%	
	May	152	606	609	505	542	75%	75%	70%	72%	
	Jun	235	774	514	636	511	70%	54%	63%	54%	
	Jul	424	660	617	743	441	36%	31%	43%	4%	
	Aug	566	815	735	836	646	31%	23%	32%	12%	
	Sep	655	818	753	908	896	20%	13%	28%	27%	
	Oct	734	935	825	899	692	21%	11%	18%	-6%	
	Total	461	738	706	787	624	39%	37%	44%	27%	
Middle River	Mar	531	653	330	821	838	19%	-61%	35%	37%	32%
	Apr	339	412	553	500	864	18%	39%	32%	61%	
	May	143	474	504	441	659	70%	72%	68%	78%	
	Jun	216	477	314	429	759	55%	31%	50%	72%	
	Jul	333	400	308	333	825	17%	-8%	0%	60%	
	Aug	366	399	385	475	899	8%	5%	23%	59%	
	Sep	477	390	433	632	614	-	-10%	24%	22%	
	Oct	436	643	470	551	800	32%	7%	21%	46%	
	Total	355	481	412	523	782	25%	19%	32%	54%	
Yearly Average						43%	42%	46%	40%	43%	

Figure 2-2. Average monthly specific conductance in relation to the barriers

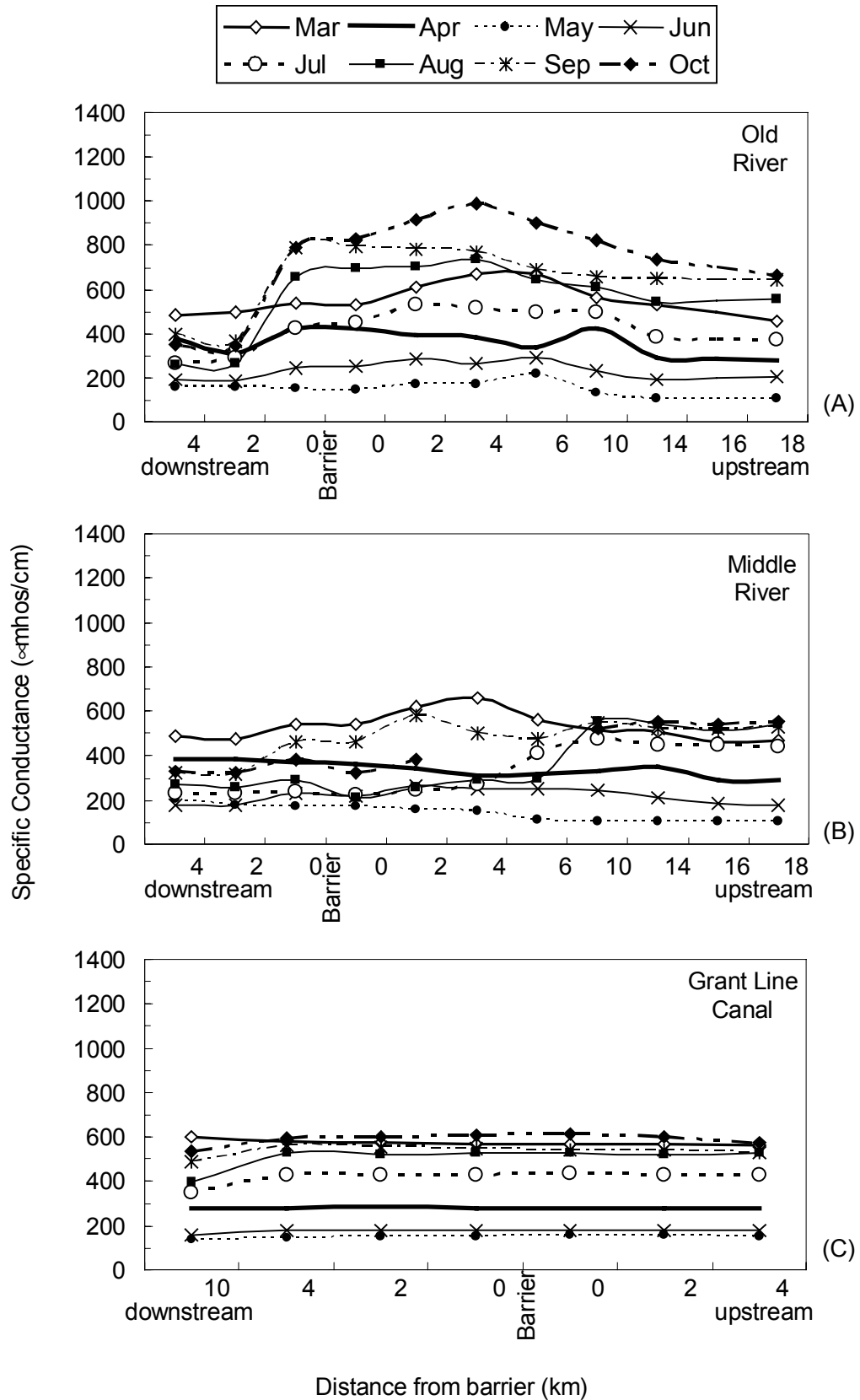


Figure 2-3. Average monthly dissolved oxygen in relation to the barriers

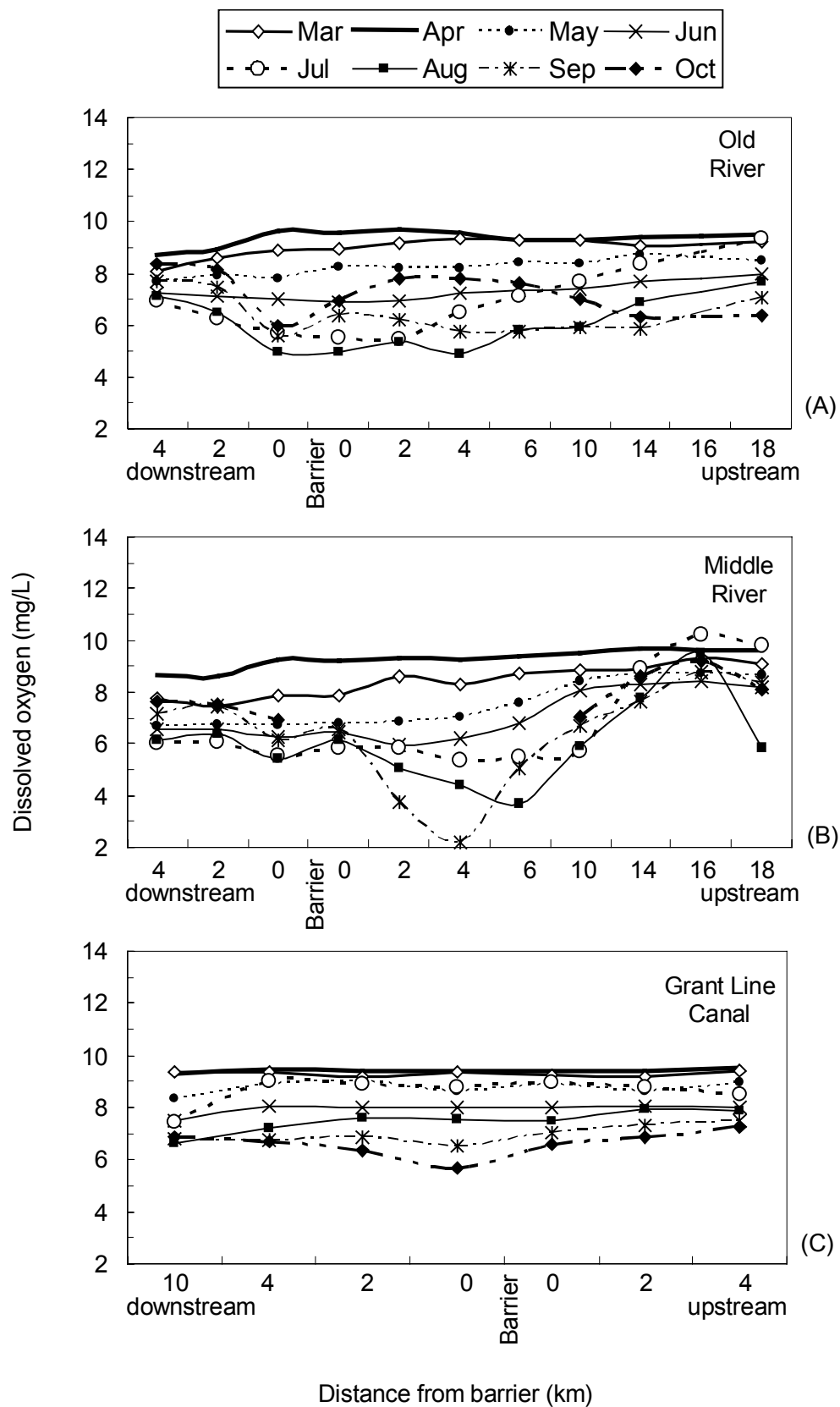


Figure 2-4. Average monthly water temperature in relation to the barriers

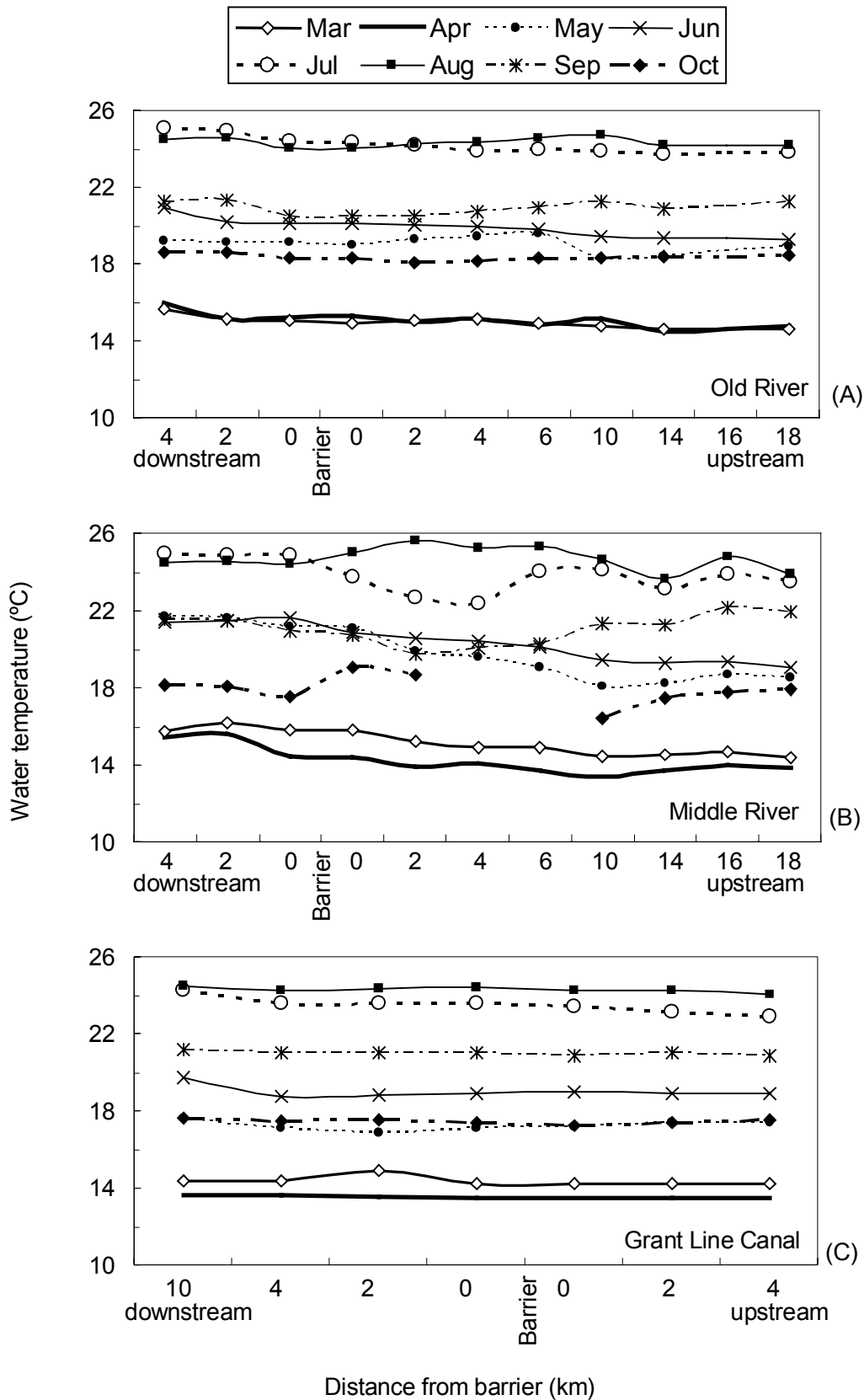


Figure 2-5. Average monthly turbidity in relation to the barriers

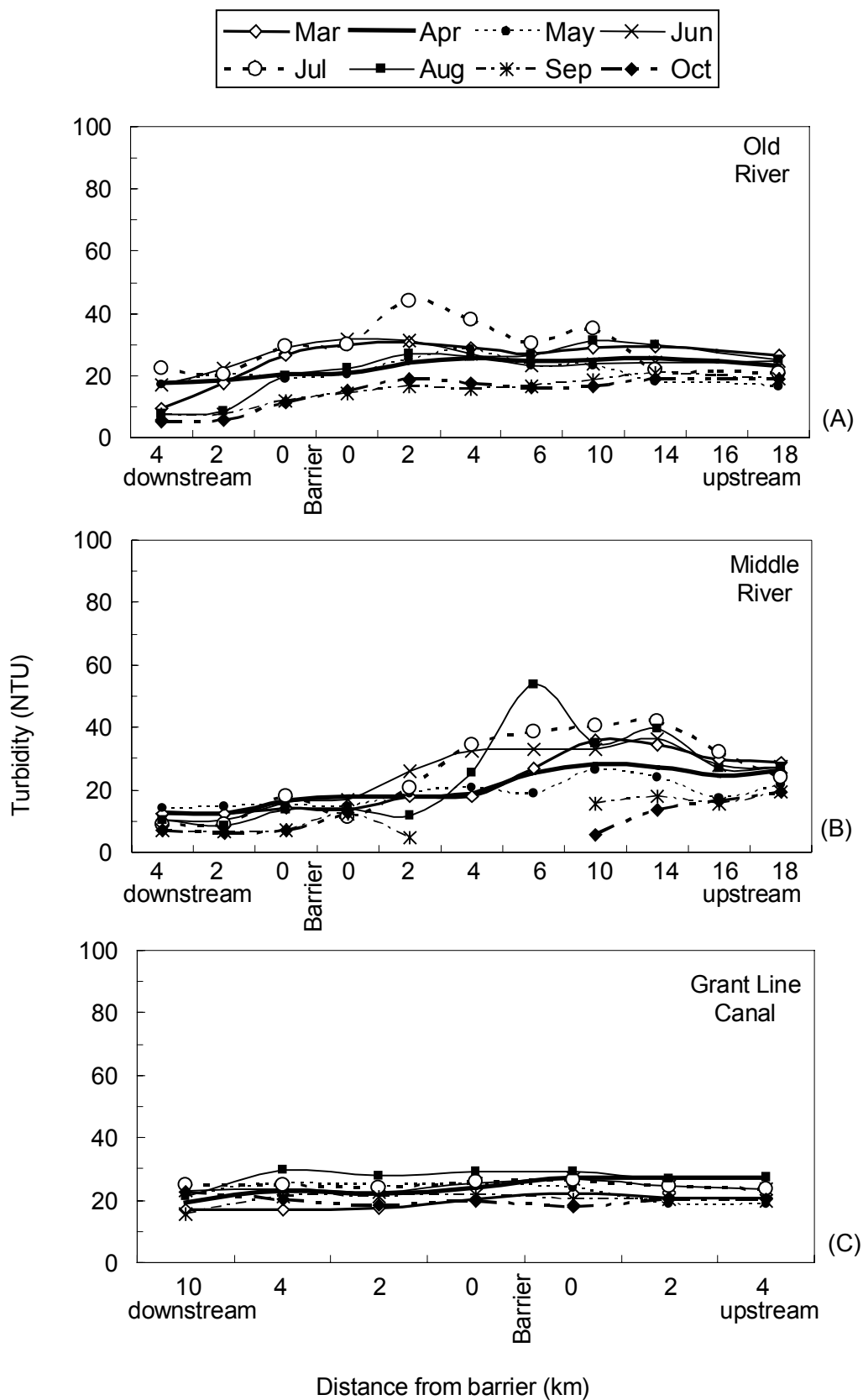


Figure 2-6. Average water quality parameters in relation to the barriers. Grant Line Canal was sampled 10km downstream to 4km upstream of the barrier. Old and Middle rivers were sampled 4km downstream to 18km upstream of the barriers.

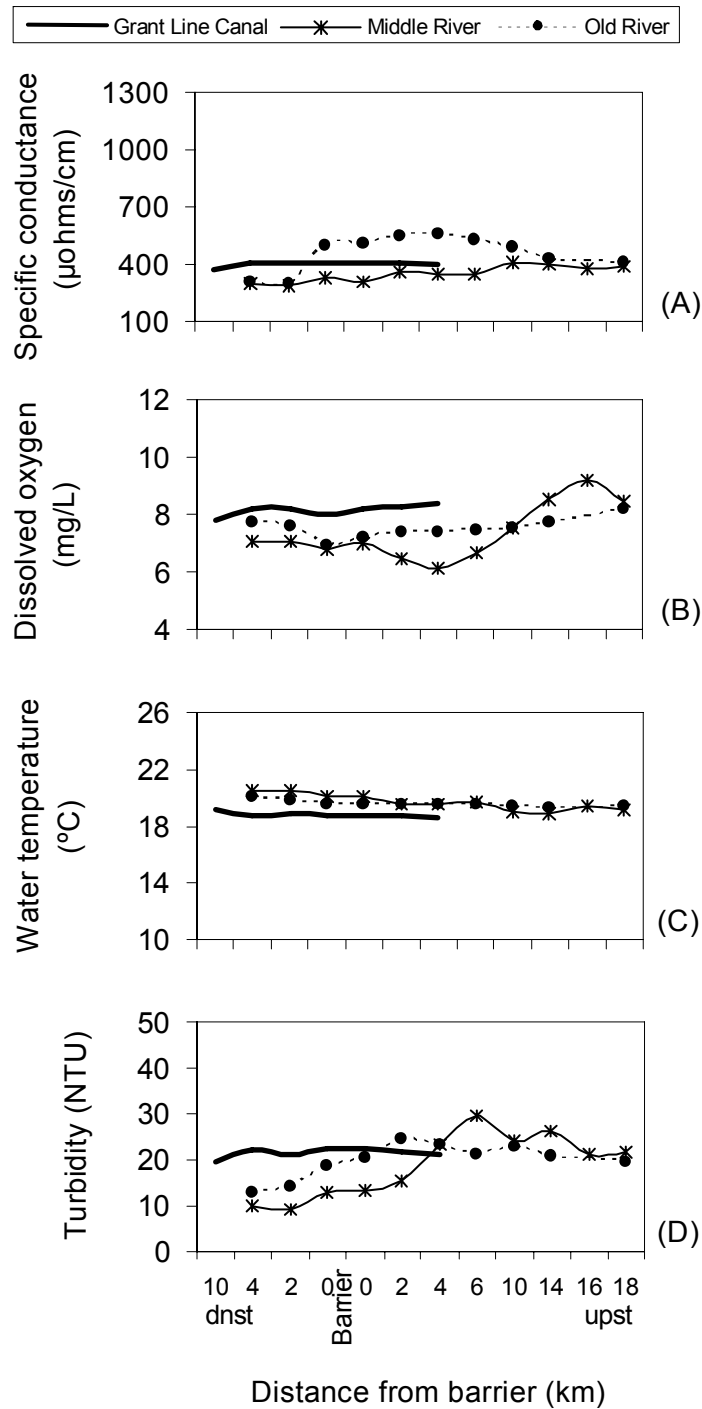


Figure 2-7. Average monthly water quality parameters

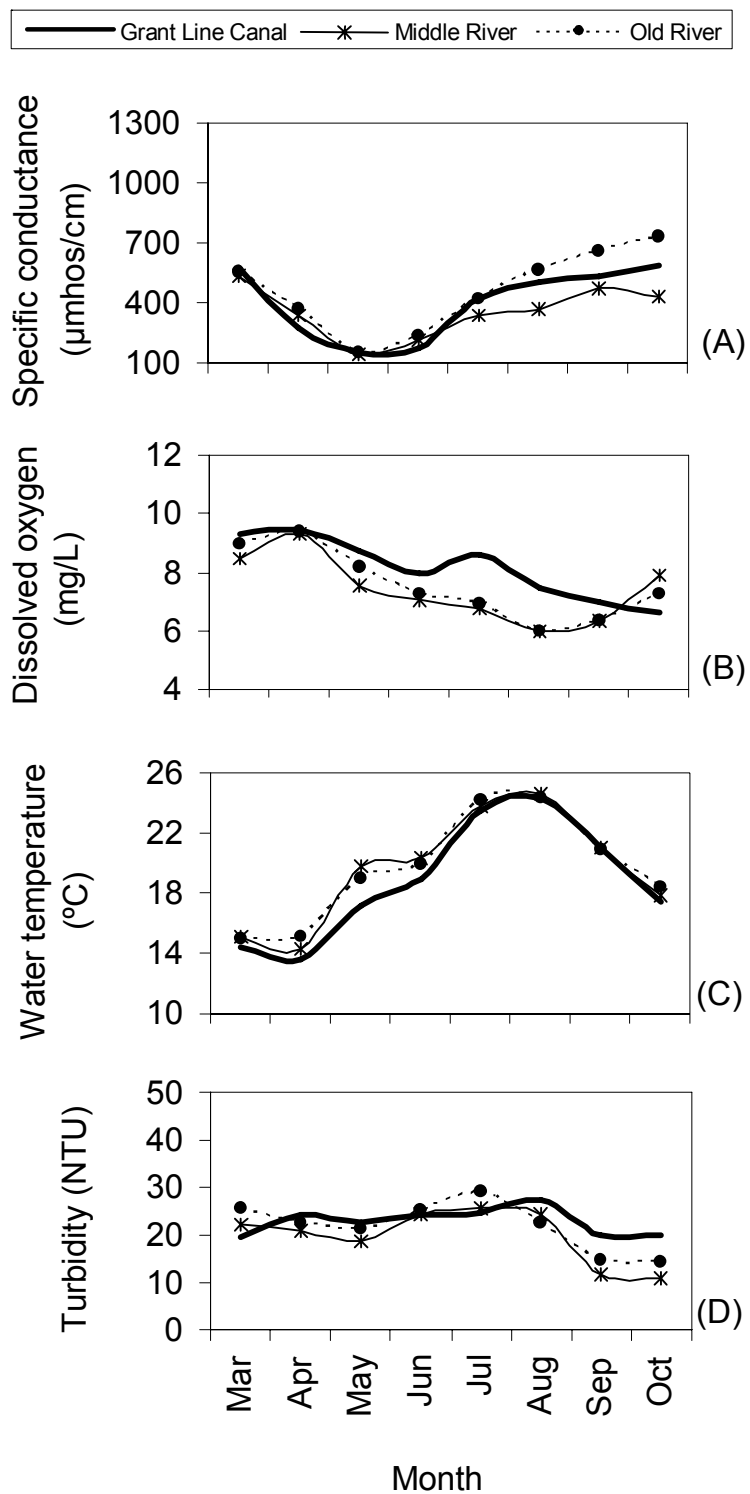


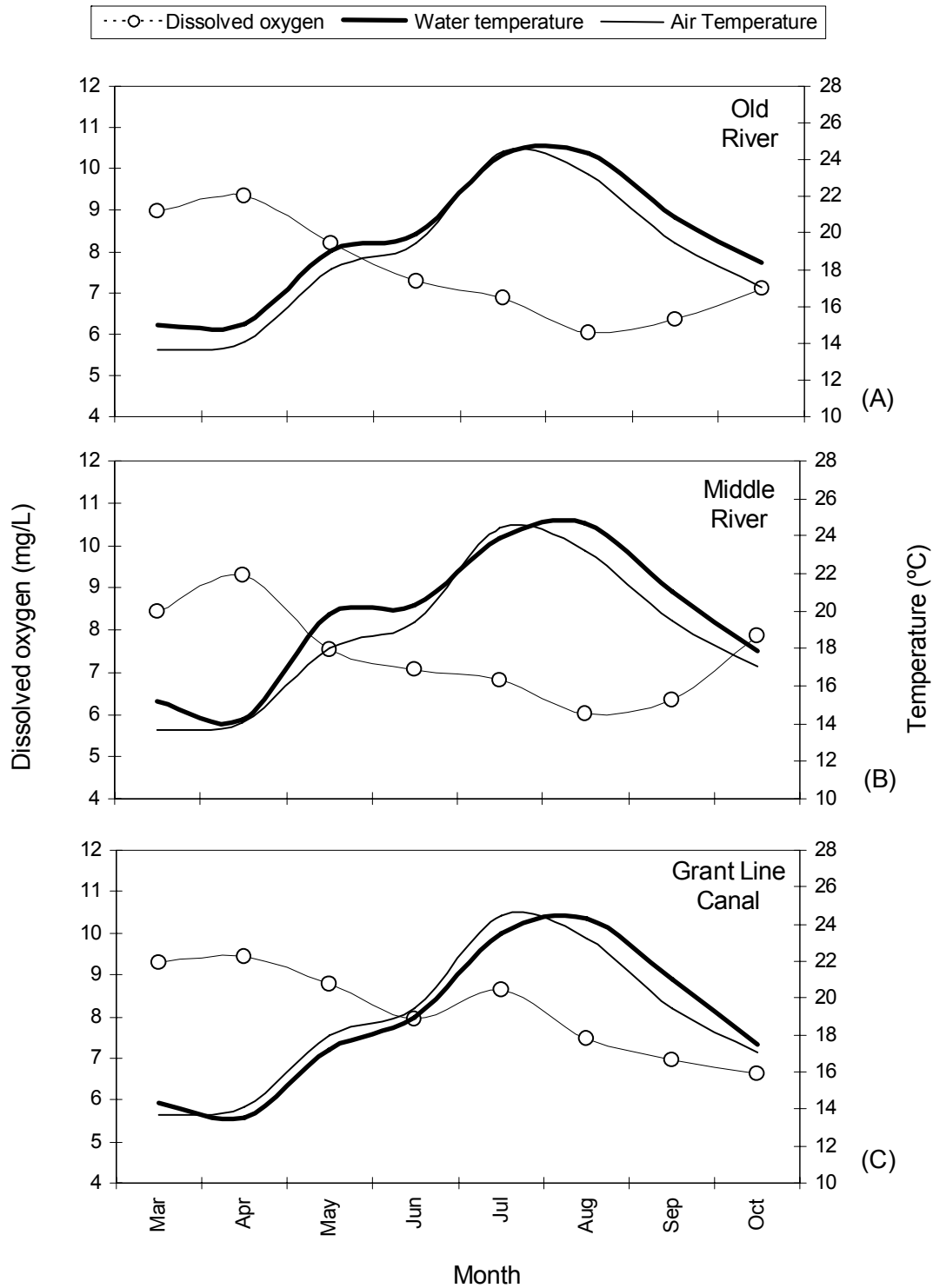
Figure 2-8. Average monthly water temperature, air temperature, and dissolved oxygen for the south Delta

Figure 2-9. San Joaquin River mean daily flows at Vernalis, California

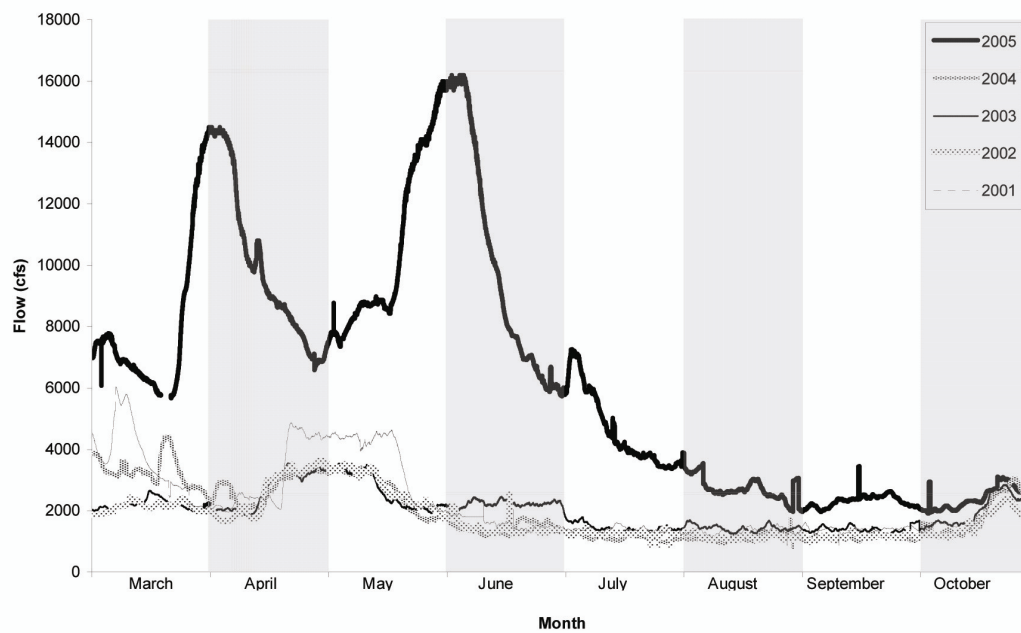


Figure 2-10. Map of possible null zones in the south Delta

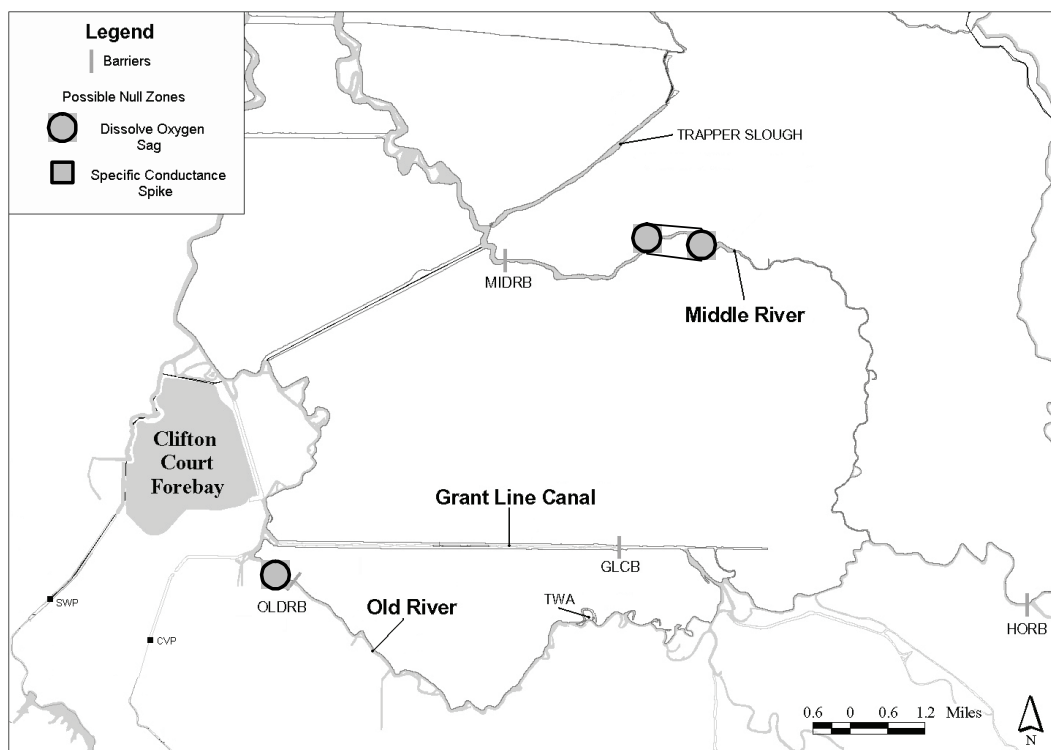


Figure 2-11. Average yearly turbidity in relation to the OLDRB including new testing sites

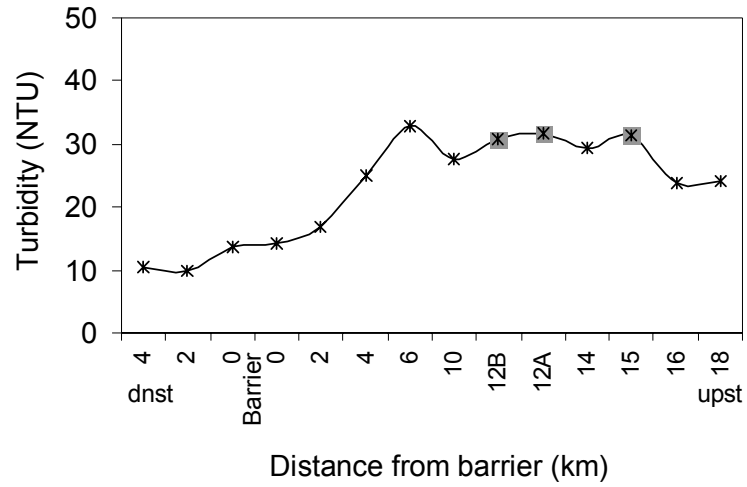
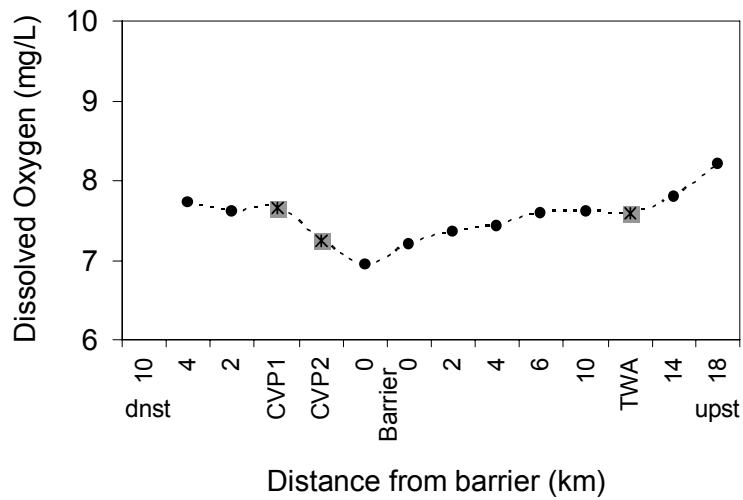


Figure 2-12. Average yearly dissolved oxygen in relation to the MIDRB including new testing sites



Chapter 3. Kodiak Trawling in Old and San Joaquin Rivers

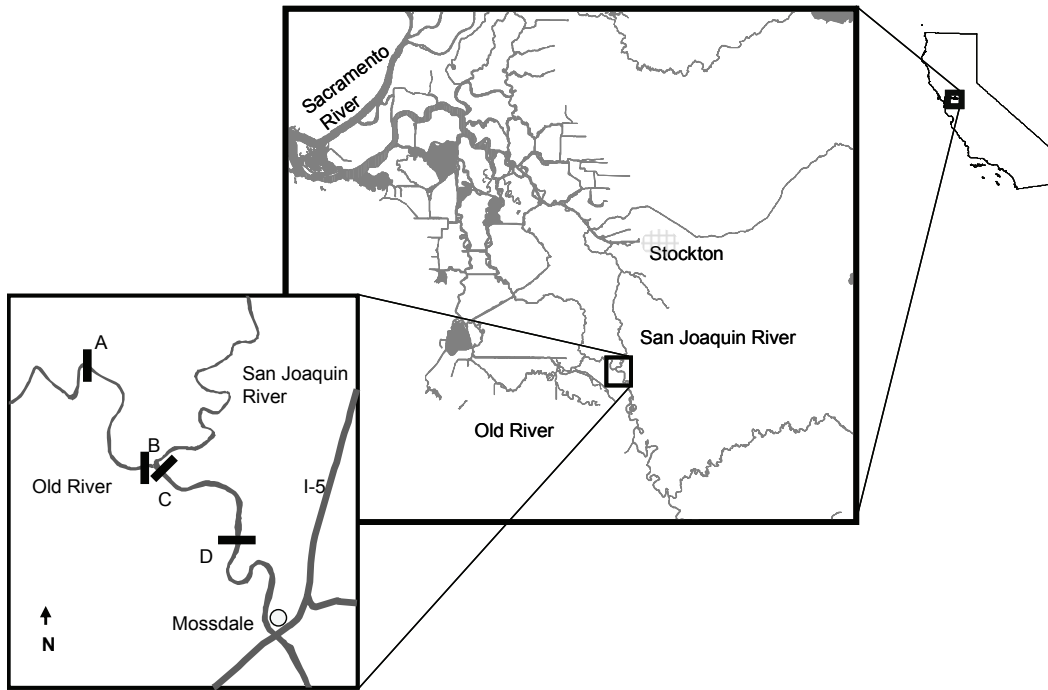
The South Delta Water Management Program was developed in 1990 to achieve two objectives. One objective was to increase water levels, improve circulation patterns and improve water quality for local agricultural diversions in the south Delta. The other objective was to improve operational flexibility of the State Water Project (SWP) to help reduce fishery impacts and improve fishery conditions. To meet these objectives, a plan was designed to have four permanent barriers placed at key locations throughout the south Delta. The South Delta Temporary Barriers Project was implemented to study the effectiveness of temporary barriers in obtaining the objectives of the permanent barriers.

A temporary barrier was designed for the head of Old River to meet the fishery objectives. The barrier is constructed where Old River diverges from the San Joaquin River, just downstream of Mossdale. This barrier is built in the spring to block the passage of out-migrating San Joaquin River juvenile Chinook salmon (*Oncorhynchus tshawytscha*) into Old River which leads to the SWP and Central Valley Project export facilities. However, the Spring Head of Old River Barrier (SHORB) was not constructed in 2005 due to San Joaquin River flows in excess of 5,000 cfs. Above normal rainfall and increased reservoir releases in late winter and early spring 2005 caused the higher flows. Because the SHORB was not constructed, there was no fish entrainment monitoring. As an alternative to the entrainment monitoring, the Department of Fish and Game (DFG) towed a Kodiak trawl in Old River during the VAMP test period. The Old River Kodiak Trawl (ORKT) was conducted in a similar manner to the Mossdale Kodiak Trawl (MKT) which is conducted year-round on the San Joaquin River. Information from the two trawls may provide insights into salmon migration from San Joaquin River into Old River.

Methods and Results

The ORKT and MKT used similar sampling gear and protocols. Fish were collected using a Kodiak trawl towed between two boats. Trawling took place in Old River, downstream of the head, and in the San Joaquin River, upstream of the head of Old River (Figure 3-1). The Kodiak trawl is 19.8 m long, made of variable mesh (ranging from 1.27 cm stretch mesh at the cod-end to 5.08 cm mesh at the mouth), and has a mouth opening of 1.83 m by 7.62 m. The effective sampling area of the net was estimated at 12.5 m² (USFWS 2003). All trawling occurred during daylight hours, starting around 0800 hrs. Typically, the MKT and ORKT started within a half hour of each other and ended within an hour of each other. The Kodiak trawl was towed against the current for 20 minutes. Although the boats and net faced upstream, the high flows carried the boats and net downstream. Typically, five tows were completed before the ORKT net was retrieved and reset upstream. A total of 15 tows per day, seven days a week, were attempted from May 2 through May 20. Boat troubles and a snagged net resulted in two days with fewer than 15 tows in Old River.

Figure 3-1. Map of the 2005 Kodiak trawl sample locations on Old and San Joaquin Rivers. The Old River Kodiak trawl sampled between A and B, and the Mossdale Kodiak trawl sampled between C and D.



For the ORKT, all fish were counted and measured (fork length) to the nearest millimeter. All salmon were checked for a clipped adipose fin or spray dyed color-mark. Salmon with a clipped adipose fin were sacrificed for CWT reading. For this comparison of the MKT and ORKT salmon catch, CWT salmon refers to all salmon with a clipped adipose fin. The unmarked salmon catch represents both hatchery and naturally spawned salmon. A flow meter was used to estimate the volume of water sampled. All sample statistics are reported as the mean \pm standard deviation unless otherwise noted. The average volume of water sampled per tow by the MKT ($10,520 \pm 2,216 \text{ m}^3$) was greater than the ORKT ($7,224 \pm 1,074 \text{ m}^3$). Catch-per-unit-effort (CPUE) for both trawling efforts was standardized to the number of salmon per 10,000 m^3 . CPUE was calculated by dividing the catch by the volume (m^3) of water sampled and then multiplying the result by 10,000.

The ORKT caught approximately 1,000 fish, representing 14 species, in 276 tows during the 19 day sampling period in Old River. The most abundant species was Chinook salmon followed by splittail (*Pogonichthys macrolepidotus*) (Table 3-1). Of the 709 salmon caught, 370 were unmarked, 318 were classified as CWT, and 21 had a color-mark. A two-tailed t-test (degrees of freedom (df) = 686, Probability (P) < 0.01, t statistic = 10.0) indicated fork lengths for unmarked salmon ($95 \pm 7.9 \text{ mm}$) were significantly larger than CWT salmon fork lengths ($89 \pm 6.9 \text{ mm}$). Salmon were about twice the size of the splittail ($43 \pm 4.3 \text{ mm}$ fork length).

The MKT caught approximately 4,500 fish, representing 17 species, in 285 tows during the same 19 day sampling period in the San Joaquin River. The most abundant species caught was splittail followed by Chinook salmon (Table 3-1). Of the 1,534 salmon caught, 812 were unmarked, 466 were classified as CWT, and 256 had a color-mark. For the 19 day sampling period, the mean length for unmarked salmon ($95 \pm 7.5 \text{ mm}$) was significantly (df = 1261, P <

0.01, $t = 16.1$) larger than the mean length for CWT salmon (88 ± 7.3 mm). The mean unmarked salmon CPUEs in the MKT, from March through June, were highest during the VAMP period (Figure 3-2). Splittail (mean fork length was 38 ± 6.8 mm) in the MKT were significantly smaller than splittail caught in the ORKT ($df = 3,097$, $P < 0.01$, $t = 3.5$).

As part of the VAMP salmon survival studies, roughly 100,000 CWT salmon were released at Durham Ferry on May 2 and again on May 9. CWT salmon catch was the highest on May 3 in both Old River (Figure 3-3) and San Joaquin River (Figure 3-4). Overall, ORKT recaptured very few of the Durham Ferry released salmon. More salmon were recaptured from the May 2 release (77 salmon) than from the May 9 release (21 salmon).

Table 3-1. The raw abundance and composition of fishes caught in the Kodiak trawl in Old River (ORKT) and in the San Joaquin River (MKT) for trawls conducted May 2-20, 2005. Chinook salmon catch is divided into CWT salmon, unmarked salmon, and color-marked salmon.

Species	ORKT	MKT
Bigscale Logperch	1	
Black Crappie	1	1
Bluegill	6	1
Carp	11	2
Channel Catfish	2	1
Goldfish		7
Golden Shiner		6
Inland Silverside	1	9
Largemouth Bass		3
Redear Sunfish	2	2
Red Shiner		3
Sacramento Blackfish		2
Sacramento Pikeminnow	1	5
Sacramento Sucker	1	
Splittail	218	2,917
Steelhead	4	4
Striped Bass	3	
Threadfin shad	28	61
White Catfish	27	5
Chinook Salmon	709	1,534
CWT Salmon	318	466
Unmarked Salmon	370	812
Color-Marked Salmon	21	256
Total	1,015	4,563

Figure 3-2. The average daily densities of unmarked salmon caught in the Mossdale Kodiak trawl on the San Joaquin River

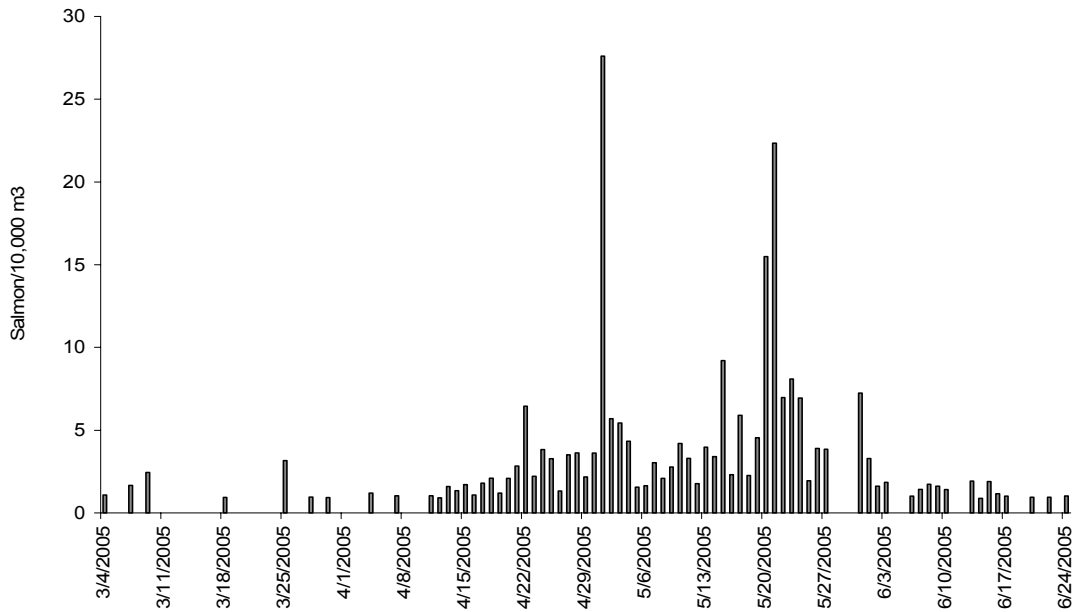


Figure 3-3. The total number of salmon by category (color-marked, coded wire tagged, and unmarked) caught in daily five hour Kodiak trawling sessions (150,000 m³) in the San Joaquin River

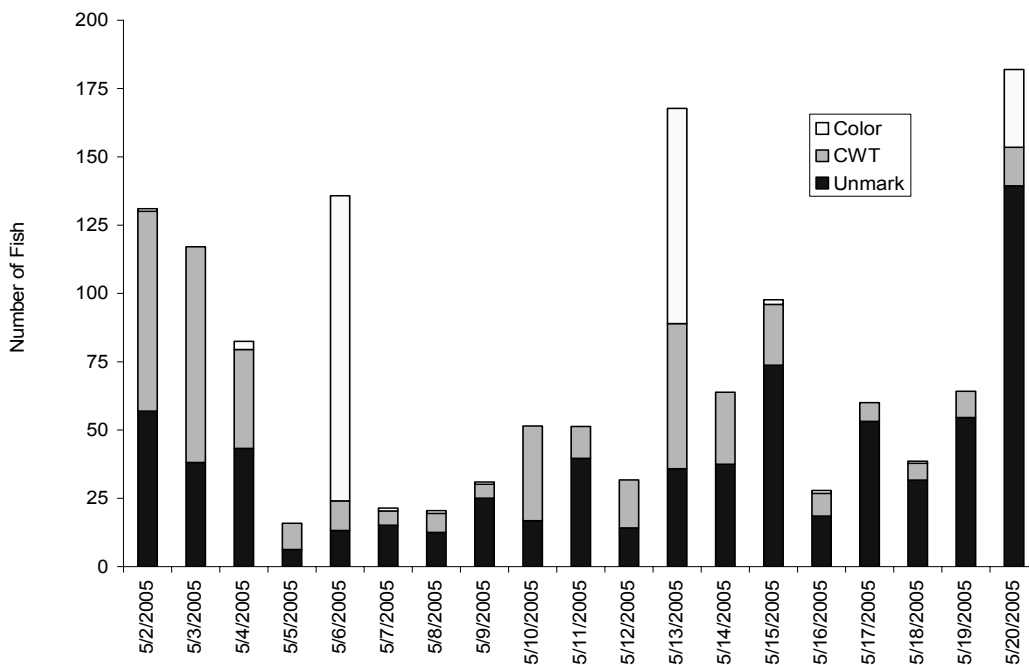


Figure 3-4. The total number of salmon by category (color-marked, coded wire tagged, and unmarked) caught in daily five hour Kodiak trawling sessions (150,000 m³) in Old River

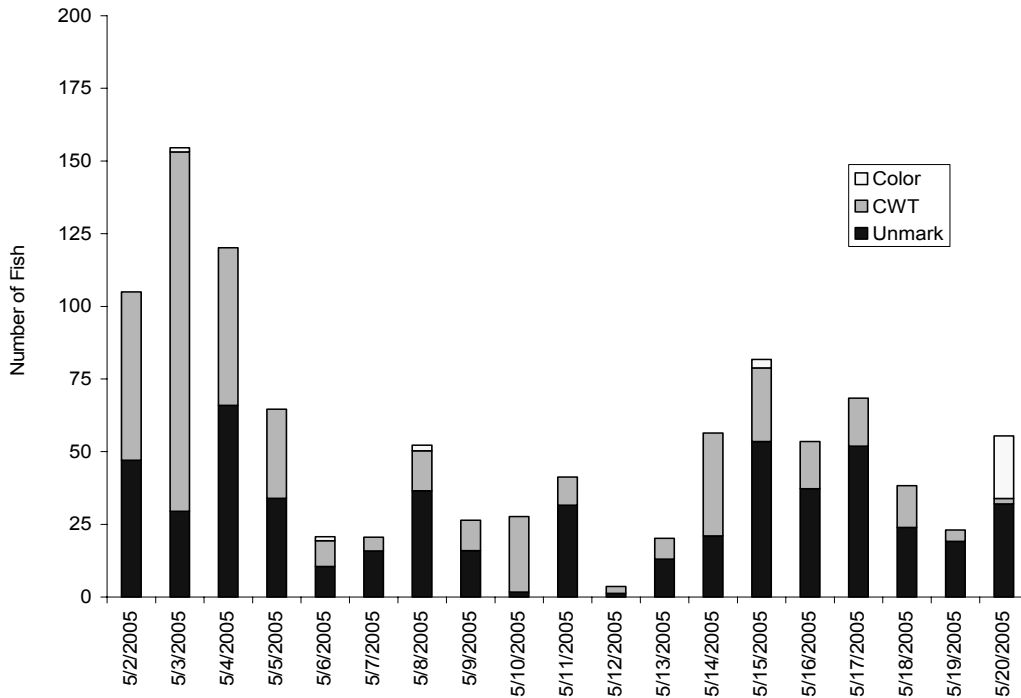
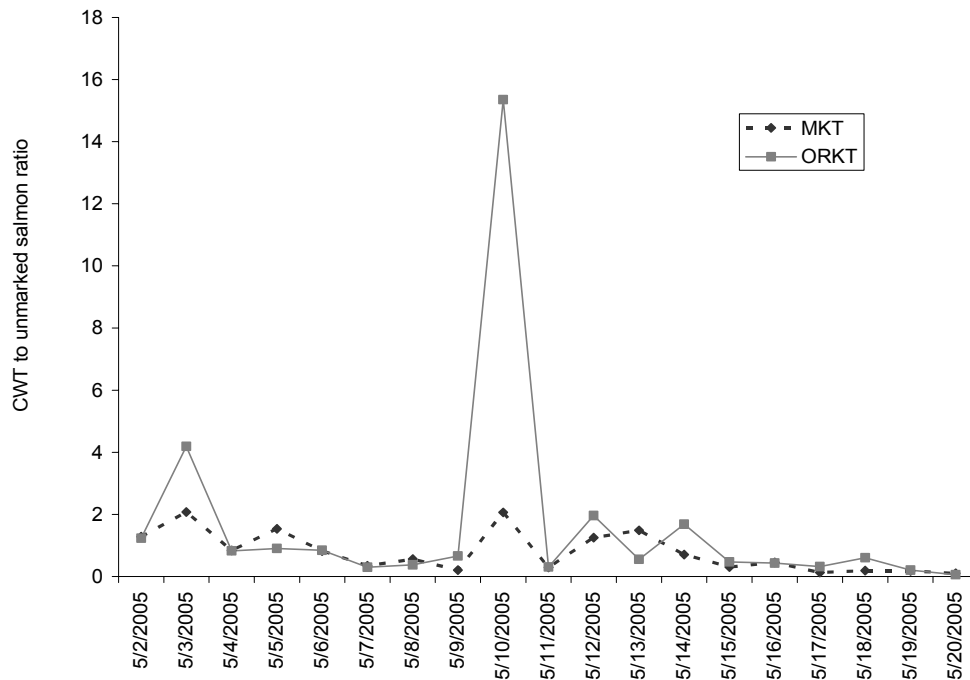


Figure 3-5. The ratio of CWT salmon to unmarked salmon caught in the Old River Kodiak trawl (ORKT) on Old River and the Mossdale Kodiak trawl (MKT) on the San Joaquin River



To determine if CWT salmon were migrating similarly to unmarked salmon into the Old River, their daily ratios were compared between trawls. The daily ratio of CWT salmon to unmarked salmon was similar between the ORKT and MKT, although CWT salmon were proportionally higher in the ORKT during the VAMP salmon releases (Figure 3-5). The daily ratios of CWT to unmarked salmon were converted to percentages (percent of the combined CWT and unmarked catch) and arcsine transformed before testing whether there was a significant difference between the ORKT and MKT. A paired two-tailed t-test ($df = 18$, $P = 0.13$, t statistic = -1.60) indicates no significant difference in the daily percent of CWT salmon caught between the ORKT and MKT.

In order to compare salmon abundance between the San Joaquin River and Old River, salmon densities (calculated from the Kodiak trawls) were expanded by river flow and trawling duration. The following equation was used:

E = estimated number of salmon

D = fish density (fish/m³)

F = river flow (m³/s) during sampling

T = trawling time (s)

i = ith tow

n = last tow with fish

$$E = \sum_{i=1}^n D_i * F_i * T_i$$

To determine how well this equation estimates salmon abundance in the San Joaquin River, estimates for color-marked salmon were calculated and compared to the number of color-marked fish released. Eight groups of color-marked fish were released at Mossdale as part of DFG Region IV's MKT vulnerability study. It was assumed all color-marked fish released upstream of the MKT, at Mossdale, passed the MKT while they were trawling. Three of the color-mark groups were released when both MKT and ORKT were sampling. The estimated number of color-marked fish passing the MKT ranged from 6 % to 138 % of the color-marked salmon released upstream of the trawl, and averaged 50 % \pm 38 % (Table 3-2). ORKT only caught color-marked salmon from the May 20 release (Table 3-3).

Table 3-2. The estimated number (Est. No.) of color-marked fish as calculated from the Mossdale Kodiak trawl (Salmon density (fish/m³)* Time (s)*Flow (m³/sec)) compared to the number of fish released upstream

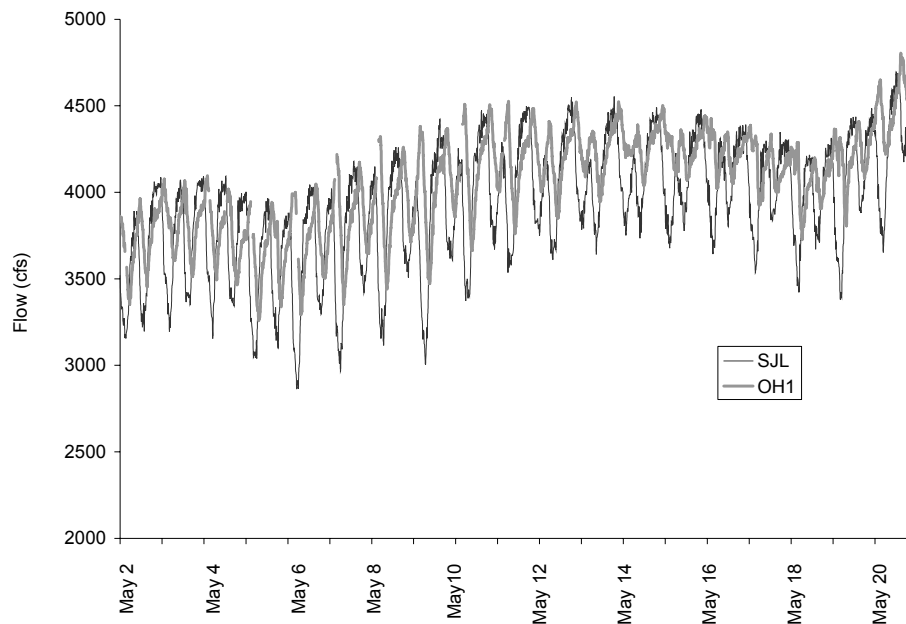
Date	Flow (cfs)	Salmon Density	Est. No.	Released	Percent
4/6/2005	363 (12,800)	0.000100	130	2,036	6%
4/15/2005	241 (8,518)	0.000767	1,997	5,068	39%
4/22/2005	200 (7,077)	0.001300	938	2,000	47%
4/29/2005	179 (6,337)	0.000778	1,507	5,000	30%
5/6/2005	207 (7,301)	0.003700	2,754	2,003	138%
5/13/2005	223 (7,882)	0.001580	2,116	5,000	42%
5/20/2005	252 (8,910)	0.000933	848	2,001	42%
5/27/2005	328 (11,576)	0.000540	1,062	2,000	53%

Table 3-3. Total raw catch (first nine tows only) in the Mossdale and Old River Kodiak trawls, by tow and time, for three color-marked salmon releases on the San Joaquin River at Mossdale Landing. An asterisk indicates the Kodiak trawl in Old River was moved back upstream.

Tow	RedUC/Do (5/6/2005)		RedUC (5/13/2005)		RedLC (5/20/2005)	
	Mossdale	Old River	Mossdale	Old River	Mossdale	Old River
	Catch Time	Catch Time	Catch Time	Catch Time	Catch Time	Catch Time
1	0 (8:12)	0 (8:04)	0 (8:29)	0 (8:23)	0 (8:08)	0 (7:35)
2	72 (8:35)	0 (8:29)	6 (8:53)	0 (8:47)	0 (8:32)	0 (8:01)
3	59 (8:59)	0 (8:54)	19 (9:17)	0 (9:12)	25 (8:55)	0 (8:26)
4	3 (9:23)	0 (9:18)	53 (9:40)	0 (9:37)	2 (9:17)	0 (8:51)
5	0 (9:46)	0 (9:42)	1 (10:05)	0 (10:02)	2 (9:41)	* 0 (9:32)
6	0 (10:10)	0 (10:06)	2 (10:41)	* 0 (10:55)	0 (10:04)	12 (9:50)
7	0 (10:33)	* 0 (10:53)	0 (11:04)	0 (11:20)	0 (10:28)	0 (10:15)
8	0 (10:57)	0 (11:17)	0 (11:28)	0 (11:45)	0 (10:51)	4 (10:46)
9	0 (11:20)	0 (11:42)	0 (11:51)	0 (12:10)	0 (11:26)	* 0 (11:26)
Total catch	134	0	81	0	29	16

Flow data for the head of Old River (OH1) and San Joaquin River below Old River near Lathrop (SJL) were obtained from the California Data Exchange Center (<http://cdec.water.ca.gov>). Estimated flow on the San Joaquin River above Old River was calculated by summing flows from OH1 and SJL. The flow was split approximately equally between Old River and the San Joaquin River from May 2 through May 20 (Figure 3-6). The percent of water flowing down Old River ranged from 47 % (3,259 cfs) to 58 % (4,387 cfs), and averaged 51 % (4,060 cfs) \pm 2 % (292 cfs).

As a general comparison of flows and fish between Old and San Joaquin Rivers, a daily five hour fish abundance estimate was calculated for CWT salmon, unmarked salmon, and splittail. The fish abundance estimates were calculated using the previously mentioned equation; however, all daily 20 minute tows ($n = 15$) were used in the calculation. On a daily average, 55 ± 61 % of the unmarked salmon, 64 ± 43 % of the CWT salmon, and only 5 ± 4 % of the splittail estimated in the San Joaquin River migrated down Old River (Table 3-4).

Figure 3-6. Flow at the head of Old River (OH1) and near Lathrop on the San Joaquin River (SJL) during the 2005 Kodiak trawl survey**Table 3-4. Estimated total number unmarked salmon, CWT salmon, and splittail in a section of the San Joaquin River and Old River, for a 5 hour period per day, and the estimated percent migrating down Old River. Estimates based on salmon densities from the Kodiak trawls multiplied by flow and trawling time.**

Date	San Joaquin River			Old River			Percent down Old River		
	Unmark	CWT	SPT	Unmark	CWT	SPT	Unmark	CWT	SPT
5/2/05	1,411	1,811	16	600	739	0	43%	41%	0%
5/3/05	994	2,061	2	390	1,633	0	39%	79%	0%
5/4/05	1,133	947	24	862	709	0	76%	75%	0%
5/5/05	158	244	28	423	382	2	267%	157%	4%
5/6/05	340	280	57	131	111	3	39%	40%	2%
5/7/05	400	136	67	201	61	1	50%	45%	1%
5/8/05	334	186	22	471	176	4	141%	95%	9%
5/9/05	670	138	48	208	137	9	31%	99%	9%
5/10/05	460	950	50	23	350	8	5%	37%	8%
5/11/05	1,095	321	94	432	132	1	39%	41%	1%
5/12/05	389	487	80	17	33	3	4%	7%	2%
5/13/05	993	1,476	144	181	100	11	18%	7%	4%
5/14/05	1,050	738	63	299	504	18	29%	68%	14%
5/15/05	2,059	621	96	765	361	15	37%	58%	8%
5/16/05	518	233	205	534	232	42	103%	100%	10%
5/17/05	1,491	193	200	738	234	51	50%	121%	13%
5/18/05	874	169	651	331	199	60	38%	118%	5%
5/19/05	1,581	279	711	275	56	65	17%	20%	5%
5/20/05	4,292	434	120	491	29	8	11%	7%	3%
Mean							55%	64%	5%
Std. dev.							61%	43%	4%

Discussion

For the most part, trawling went well in Old River. Boat engine problems resulted in eight missed tows on the first day and a snagged net resulted in one missed tow on another day. MKT was able to complete all their tows during this time period.

Direct comparisons between ORKT and MKT are difficult for a variety of reasons. Biases that can affect catch include the habitat (channel width, depth and flow are not the same between and within the sample sites), the sporadic and uneven distribution of migrating salmon, boat and crew differences affecting how the Kodiak net is towed, and MKT and ORKT flow meters might have different calibrations which would effect water volume calculations. Using the ratio of CWT to unmarked salmon in each trawl minimizes some of these biases and other sampling differences, and allows the two rivers to be compared with some certainty. Although direct CPUE comparisons and abundance estimates are presented here, they are to provide general insights to salmon movement and must be viewed with caution.

To determine if marked salmon had a similar migration rate into Old River as unmarked salmon, the daily percent of CWT salmon was compared between the two rivers. Proportionally, CWT and unmarked salmon were migrating down Old River at the same rate. It appears the marking and subsequent release does not affect salmon outmigration relative to the unmarked fish. Although during the Durham Ferry releases, a higher proportion of CWT went down Old River compared to unmarked salmon. There might be some differences for the Durham Ferry released salmon. Once the CWT salmon results from the MKT are available, the Durham Ferry salmon catch can be compared to the other CWT salmon catches to specifically find if there is a migration difference into Old River for in-delta salmon releases.

It is not possible to determine the total number of Durham Ferry released CWT salmon that migrated down Old River. The ORKT caught very few salmon (combined, less than 0.05 %) from the two Durham Ferry releases. The 2002-2004 results from the 24 hour entrainment studies at the SHORB indicate salmon released around noon at Durham Ferry start reaching the head of Old River in about 12 hours. Consequently, entrainment of Durham Ferry salmon is highest (63 ± 20 %) during the first night following a fish release. Only 16 ± 15 % of the total Durham Ferry salmon entrainment occurs during the following day. Extrapolating the ORKT day results to include the nighttime period would greatly underestimate the number of Durham Ferry fish migrating down Old River.

ORKT and the MKT salmon abundance estimates were calculated using the same method. Salmon abundance was estimated by multiplying salmon density by river flow and trawling duration. Although the abundance estimates based on the MKT vulnerability study might be more accurate, this method was not used since no vulnerability study was conducted in Old River. However, the color-marked salmon vulnerability study releases were used to provide information on the accuracy of the MKT salmon abundance estimates. The range in the accuracy of the eight estimates (Table 3-4) might be caused by several factors, such as the uneven distribution of salmon as they migrate downstream, the variability in trawling, and the ability to detect the color-mark on recaptured fish. On average, it appeared the MKT underestimated the color-marked fish by half. Thus, a correction factor could be used with these calculations to get a better estimate of outmigrating salmon.

The ORKT would probably have a smaller correction factor compared to the MKT. Since the channel is narrower in Old River than it is in the San Joaquin River, ORKT sampled a larger percentage of the channel width. The resulting calculated fish densities in Old River might be closer to the actual densities than the densities calculated in the San Joaquin River. Consequently, salmon catch in the MKT would be adjusted upward to a greater degree than in the ORKT.

Adjusting both the MKT and ORKT for catch efficiencies would probably decrease the daily calculated percentages of salmon heading down Old River that are presented in Table 3-4.

Color-marked salmon released for the MKT vulnerability study were not recaptured by the ORKT on two of the three releases that occurred while ORKT was sampling. The most likely reason for the zero catch is that the net was being moved back upstream while the marked fish were migrating down Old River. Based on the timing of the MKT catch and the time ORKT caught color-marked fish in Old River, the boats trawling in Old River reached the end of the sampling area and picked up the net before the color-marked fish arrived. The net was then reset upstream (around 1100 hrs) after the color-marked fish entered Old River. This means that an approximately 1.5 mile stretch of river is not sampled as the net is moved back upstream. Any fish in this section of the stream will pass by undetected. On May 20, when color-marked fish were caught, the net was reset upstream earlier (0930 hrs). The ORKT was sampling near the head when marked fish entered Old River.

An attempt was made to estimate the number of salmon migrating down Old and San Joaquin River during the trawling periods. For these comparisons, it was assumed catch efficiency was the same between the ORKT and MKT. As previously mentioned, the catch efficiency is probably different between the two trawls. Although we can correct for the MKT estimates based on the color-marked salmon releases, we have no correction for ORKT; thus, neither catch was adjusted. These abundance estimates are probably underestimating, to a different degree, the actual number of salmon in each river. When catch is adjusted for flow, it appears on a daily basis that a little more than half of the salmon in the San Joaquin River turn down Old River. During this time period, half of the San Joaquin River flow was also heading down Old River. In general terms, it appears salmon are going with the flow.

When comparing the ORKT and MKT salmon abundance estimates, the daily percentage of CWT and unmarked salmon heading down Old River is similar on most days. These results are similar to the previously mentioned CWT to unmarked salmon percent analysis. However, there is some variability among sampling days. If salmon always migrated in proportion to the flow split, we would expect low variability among the daily percentages of salmon migrating down Old River. However, the variability around the mean for both unmarked and CWT is large, e.g. ranges from 4 % to 267 % for unmarked salmon. The reason for this variability could be due to the natural variability in salmon migration which might then be compounded by trawling biases.

The 2005 flow-catch results differ from the 1995 Real-Time Monitoring (RTM) Program's Kodiak trawling results on the San Joaquin River at Dos Reis and head of Old River. RTM trawling indicated salmon densities were higher, except on one sampling day, in Old River than in the San Joaquin River (IEP 1996). In order to more accurately compare the 1995 RTM results to the 2005 Kodiak trawl results, the raw data from the 1995 Dos Reis and Old River trawls were obtained from the USFWS. The 1995 data was then analyzed using the same methods that were used on the 2005 data. For the 1995 trawling, it was assumed the catch efficiencies were the same between rivers. River flows at OH1 and SJL during the 1995 Kodiak trawling period (8 days) were estimated by using Vernalis flows and equating it to OH1 and SJL flows through regression analyses. On average, flows at OH1 were calculated at $9,971 \pm 462$ (95 % confidence interval) cfs and at SJL $8,812 \pm 658$ (95 % confidence interval) cfs. An estimated 53 % of the San Joaquin River flow went down Old River. When salmon density is expanded by flow, it appears on a daily average, 66 ± 17 % of the unmarked salmon and 70 ± 18 % of the CWT salmon migrated down Old River. These percentages are higher than the 2005 percentages for Old River. This could be due to the higher flows in 1995, compared to 2005, which might change downstream migration routes.

The RTM results also might be affected by the order in which Dos Reis and Old River were sampled. A single crew conducted five tows at Dos Reis and Old River. The Old River site was always sampled first, in the morning, and Dos Reis was sampled afterwards, late morning to midday. The higher 1995 salmon densities in Old River could be due to higher salmon activity and vulnerability in the morning than during midday. The 2005 Kodiak trawl results indicate more salmon are caught in the morning than midday. Salmon (unmarked and CWT combined) were 171 % more numerous in the first five tows than in the next five tows (tows 6 – 10) in the ORKT. In the MKT, salmon were 117 % more numerous in the first five tows than in the next five tows. If a single crew is to sample both rivers, the river sampled first should alternate to overcome any morning sampling bias.

The 2005 splittail flow-catch results differed dramatically from the salmon results. Only a fraction (5 %) of the salmon estimated on the San Joaquin River was caught in Old River. Relative to the salmon, only a tenth of the splittail were caught in Old River. It is unlikely most of the splittail migrating down the San Joaquin River remained in the San Joaquin River after the Old River split. Given the small size of the splittail, it would seem they would go with the flow, i.e. half of the splittail in the San Joaquin River would migrate down Old River. The low splittail catch in Old River is probably related to the ORKT net efficiency. While checking the Kodiak trawl on Old River, it was observed that many splittail fell through the net. Splittail length frequencies suggest the ORKT was not as efficient as the MKT in retaining small splittail. It is possible the cod-end mesh size was slightly different between the ORKT and MKT. However, salmon length frequencies were similar between the MKT and ORKT suggesting that the larger fish were not affected.

In conclusion, direct comparisons of expanded salmon abundance estimates between the ORKT and MKT were difficult due to the unknown catch efficiency of the ORKT. Although the catch efficiencies between the ORKT and MKT are probably different, they were assumed to be similar for some of the analyses. Thus, some of these results must be viewed with caution. Proportionally, there is no statistical difference on a daily basis between CWT and unmarked salmon heading down Old River. CWT and unmarked salmon are moving into Old River at a similar rate. The flow split between the San Joaquin River and Old River was 50-50. It appears juvenile salmon migrate down Old River in proportion to the flow: about half of the flow and roughly half of the salmon went down Old River. However, there was a lot of variability among the daily percentages of salmon heading down Old River. This variability might be due to natural variability in salmon migration patterns which are magnified by sampling biases and the subsequent abundance calculations. Salmon migration down Old River might also change at different river flows and pumping rates at the state and federal water projects. More data is needed to elucidate the relationship between flow and catch in Old and San Joaquin rivers.

If Kodiak trawling is conducted in future years, due to no SHORB installation, VAMP should release some of their fish at Mossdale. Salmon released at Mossdale, in the morning, would pass the Kodiak trawls in larger numbers than salmon released at Durham Ferry. This would substantially increase the CWT salmon catch in the ORKT and MKT, and might make comparisons between the two rivers a little easier. The ability to adjust catch in the ORKT based on salmon vulnerability (catch efficiency) would improve the estimate and comparison of salmon abundance to the San Joaquin River. In order for any vulnerability studies to be conducted for the ORKT, the sample site would have to be moved at least two miles downstream, and likely three to four miles, to find a suitable trawling reach. A sample site further downstream would allow time for color-marked salmon released near the head to adjust to Old River flows.

Reference Cited

- IEP. 1996. 1995 Pilot Real-Time Monitoring Program: Evaluation and Recommendations. California Department of Water Resources, Interagency Ecological Program, Technical Report 47, Sacramento, California. 39 pgs.
- USFWS. 2003. Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary. 1999 Annual Progress Report. Sacramento-San Joaquin Estuary Fisheries Resources Office, U.S. Fish and Wildlife Office, Stockton, California. 68 pgs.

Chapter 4. Salmon Smolt Survival Investigations

A primary objective of the VAMP study is to determine the effects of San Joaquin River flows, SWP and CVP water exports, and HORB installation on survival of juvenile Chinook salmon smolts emigrating from the San Joaquin River through the Delta. However, the HORB was not installed in 2005. Therefore the VAMP study was modified to accommodate these differences from past studies. This section describes the methods used to conduct the Chinook salmon smolt survival investigations and estimates survival indices, absolute survival estimates, and combined differential recovery rates for coded-wire tagged (CWT) juvenile Chinook salmon smolts released during the VAMP 2005 test period. The information gathered in 2005 was used in conjunction with past data to assess the relationships between smolt survival, river flow and CVP/SWP exports with and without the HORB. Relationships using escapement (adult salmon returning to the rivers to spawn) are also discussed.

Merced River Fish Facility Coded-Wire Tagging

Merced River Fish Facility (MRFF) supplied over 400,000 CWT Chinook salmon smolts for the VAMP 2005 study. Salmon were CWT and marked with an adipose fin clip by MRFF personnel between late March and mid-April 2005 and were generally held for approximately 27 days before release. Salmon were tagged with one of 16 distinct tag codes, depending upon where the fish were to be released. MRFF examined sub-samples of tagged salmon to estimate CWT retention rates. Average tag retention documented by MRFF was 92% and ranged from 86% to 95%. CWT detection is typically high and all salmon from the sub-samples without a detected tag were sacrificed to verify the accuracy of the CWT detection process and to determine if these fish contained an undetected, non-magnetized tag. No sub-sampled fish were found to contain non-magnetized tags.

To better estimate juvenile salmon survival through the Delta, survival estimates incorporate a measure of the VAMP Effective Number (ER) of fish that were tagged and released which accounts for tag retention rate and fish mortalities. The ER was calculated by multiplying the mortalities from the estimated number of fish transported by the tag retention rate which was then subtracted from the Hatchery Effective Number (Table 4-1).

$ER = H - (M * TR)$ where:

H = Hatchery Effective Number of CWT salmon transported. This value incorporates mortalities at the hatchery and during release and the MRFF tag retention rate.

M = number of fish sacrificed for the short-term survival studies. For the Durham Ferry and Dos Reis releases, the total numbers of fish sacrificed were divided among the tag codes based on the proportion of hatchery effective number.

TR = CWT retention rate determined at the MRFF.

Table 4-1. Chinook salmon smolt release data for VAMP 2005

Release Date	Release Site	Tag Code	Hatchery Effective Number	Fish Sacrificed for Short-Term Survival Exp.	Tag Retention Rate	Effective Number of Fish Sacrificed for Short-Term	VAMP Effective Number Released
Release 1							
2-May-05	Durham Ferry	06-46-72	23,533	127	0.94	119	23,414
2-May-05	Durham Ferry	06-46-73	23,311	126	0.94	118	23,193
2-May-05	Durham Ferry	06-46-74	23,780	128	0.94	120	23,660
2-May-05	Durham Ferry	06-46-75	23,687	128	0.94	120	23,567
Summary			94,311	508	0.94	478	93,833
3-May-05	Dos Reis	06-45-91	22,823	163	0.91	148	22,675
3-May-05	Dos Reis	06-46-97	22,444	160	0.89	142	22,302
3-May-05	Dos Reis	06-46-98	24,310	173	0.93	161	24,149
Summary			69,577	496		452	69,125
6-May-05	Jersey Point	06-45-88	23,186	450	0.93	419	22,767
Release 2							
9-May-05	Durham Ferry	06-45-84	22,874	107	0.91	97	22,777
9-May-05	Durham Ferry	06-45-85	23,066	108	0.91	98	22,968
9-May-05	Durham Ferry	06-45-86	23,110	108	0.91	98	23,012
9-May-05	Durham Ferry	06-45-87	22,903	107	0.91	97	22,806
Summary			91,953	429	0.91	390	91,563
10-May-05	Dos Reis	06-45-89	21,574	152	0.86	131	21,443
10-May-05	Dos Reis	06-45-90	23,913	169	0.94	158	23,755
10-May-05	Dos Reis	06-46-99	23,602	167	0.93	154	23,448
Summary			69,089	488		443	68,646
13-May-05	Jersey Point	06-47-00	23,562	348	0.95	331	23,231

VAMP Fish Releases

Two sets (Release 1 and Release 2) of CWT salmon were released at three sites on six dates for the 2005 VAMP experiment (Table 4-1). Releases occurred at Durham Ferry, Dos Reis, and Jersey Point. Transport and water temperatures at the time of release are listed in Table 4-2.

Durham Ferry is located on the San Joaquin River upstream of the Head of the Old River (HOR). Due to high water and poor road condition, releases were made at the top of the levee at Durham Ferry. Over 90,000 CWT salmon with four different codes were released on each occasion at Durham Ferry.

Dos Reis is located on the San Joaquin River downstream of the HOR, and was used as a release site, in lieu of Mossdale (which is upstream of HOR) in 2005 to assess the mortality of marked salmon diverted in HOR. Additionally, the release at Dos Reis was made on an ebb tide to reduce the likelihood of salmon being pushed upstream into HOR. Just fewer than 70,000 CWT salmon of three tag codes were released on each occasion at Dos Reis.

Table 4-2. Water temperature during transport and release

Release Site	Release Date	Transport Temperature (°F)	River Temperature (°F)
Durham Ferry	2-May-05	52	60
Dos Reis	3-May-05	55	63
Jersey Point	6-May-05	52	64
Durham Ferry	9-May-05	52	59
Dos Reis	10-May-05	52	59
Jersey Point	13-May-05	55	66

Jersey Point serves as a “control site” to standardize survival rates since fish released at Jersey Point do not migrate through the Delta and they are released just upstream of the Antioch and Chipps Island recovery locations. CWT salmon were released on a flood tide at Jersey Point to increase fish dispersion throughout the channel before reaching Antioch and Chipps Island (recovery sampling stations). CWT salmon from one tag code were released on each occasion (22,767 and 23,231 CWT salmon, respectively) at Jersey Point.

During the 2005 VAMP study, CWT salmon with different tag codes were held separately at the hatchery except for the fish released at Durham Ferry. During transport it was necessary to combine tag codes from the Dos Reis release, as well. Once the hatchery truck arrived at a release site, approximately 450 salmon were removed for the short-term survival study (see below). The remaining fish were then immediately released.

Water Temperature Monitoring

Water temperature was monitored during the VAMP 2005 study using individual computerized temperature recorders (e.g., Onset Stowaway Temperature Monitoring/Data loggers). Water temperatures were measured at locations along the longitudinal gradient of the San Joaquin River and interior Delta channels between Durham Ferry and Chipps Island – locations along the migratory pathway for the juvenile Chinook salmon smolts released as part of these tests (Appendix A, Table A-1). Water temperature was recorded at 24-minute intervals throughout the period of the VAMP 2005 investigations. Water temperatures were also recorded within the hatchery raceways at the MRFF coincident with the period when juvenile Chinook salmon were being tagged and held. These temperature recorders were later transported with the juvenile salmon released at Durham Ferry.

Results of water temperature monitoring within the Merced River Fish Facility showed that juvenile Chinook salmon were reared in, and acclimated to, water temperatures of approximately 9.7 °C- 11.8 °C (49.5 °F - 53.2 °F) prior to release into the lower San Joaquin River (Figures 4-1 and 4-2). Results of water temperature monitoring at Durham Ferry and Jersey Point following the VAMP 2005 releases are shown in Figures 4-3 and 4-4. This water temperature monitoring showed that water temperatures at the release locations and throughout the lower San Joaquin River and Delta (Appendix A, Figures A-2 through A-10) were higher than those at the hatchery, which is generally the case. Water temperatures measured within the lower San Joaquin River and Delta (Figures 4-3 and 4-4) were within a range considered to be suitable (< 20 °C; 68 °F) for Chinook salmon smolts and would not be expected to result in adverse effects or reduced survival of emigrating juvenile Chinook salmon released as part of the VAMP 2005 investigations.

Figure 4-1. Merced River Fish Hatchery to Durham Ferry

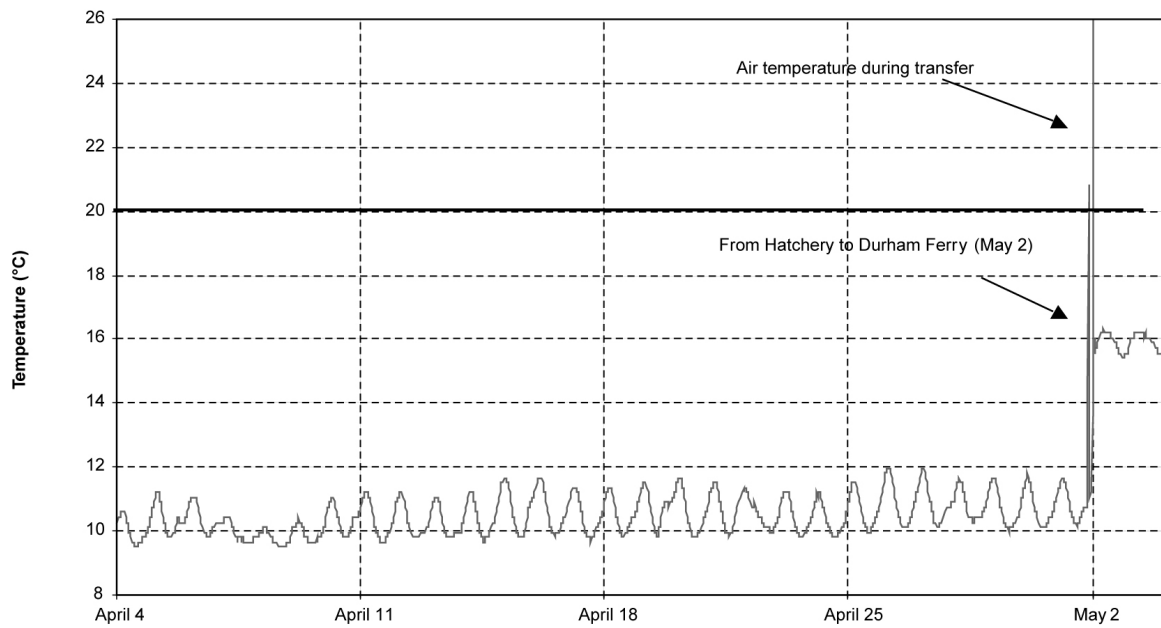


Figure 4-2. Merced River Fish Hatchery to Durham Ferry

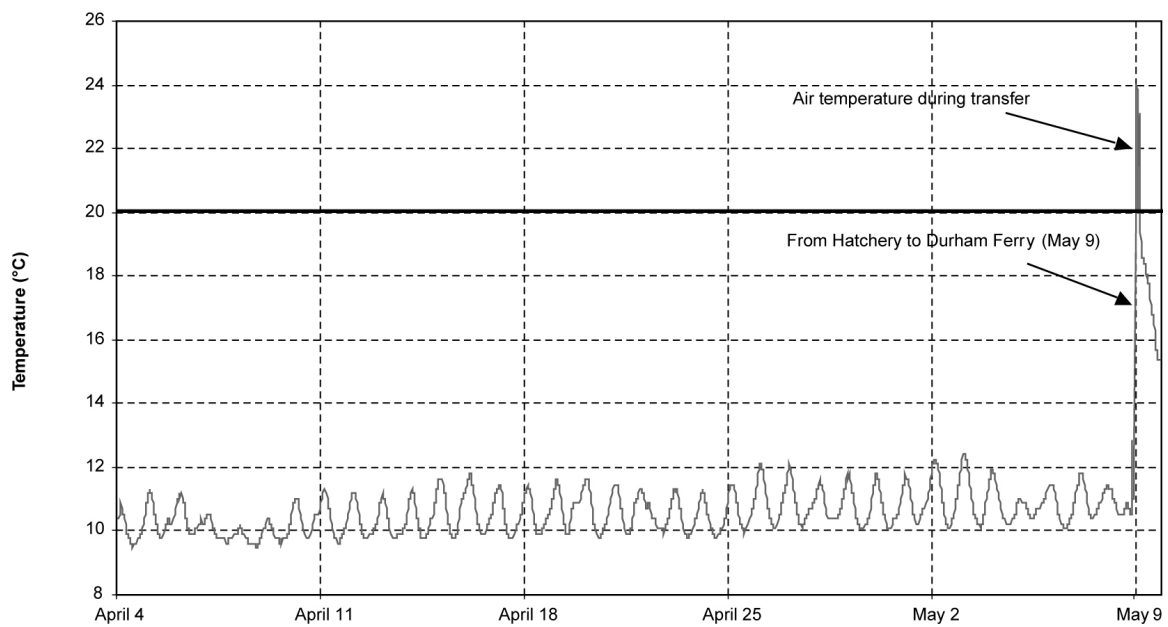
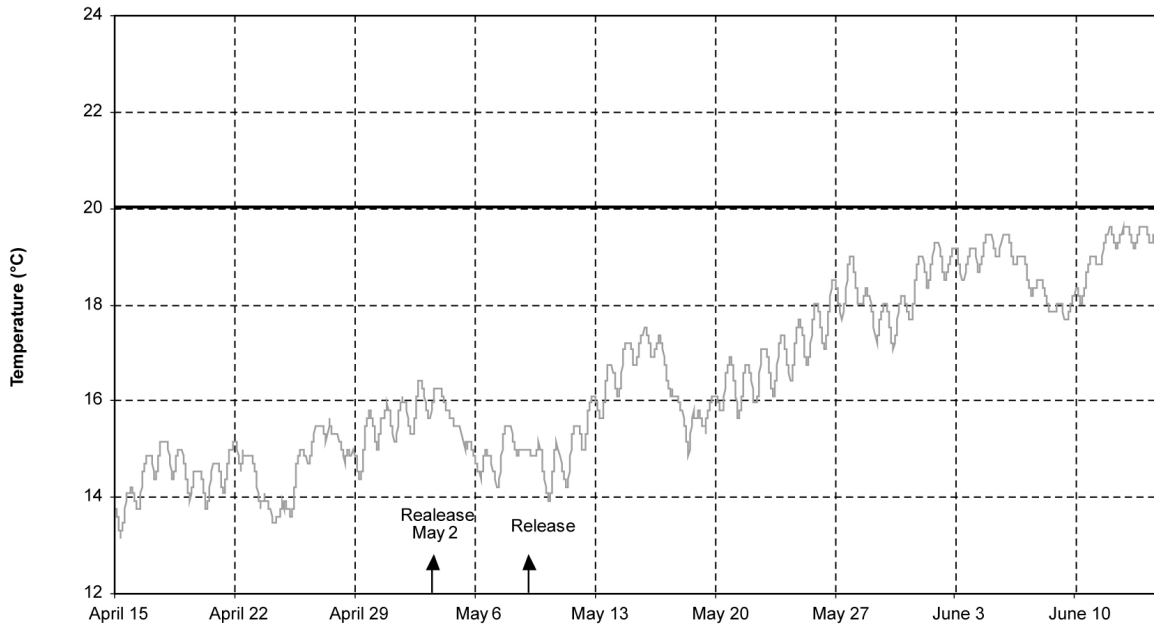
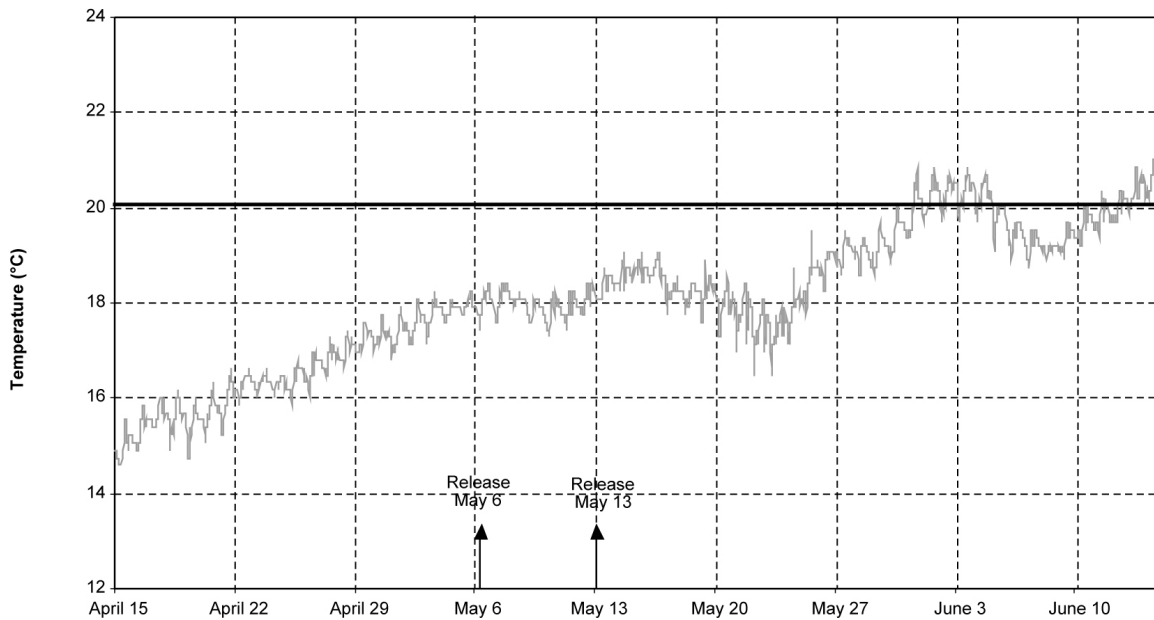


Figure 4-3. Site 1 - Durham Ferry**Figure 4-4. Site 9 - USGS Gauging Station at Jersey Point - Top**

Short-Term Survival Study

Two groups of CWT salmon were removed from the MRFF fish transport truck before each release to determine if handling, transport, and release affected short-term, 48-hour survival and general condition. The goal was to place 225 CWT fish into each of 2 net pens (volume $\sim 1\text{m}^3$; mesh size $\sim 3\text{ mm}$); however, all numbers were approximated when the fish were removed from the MRFF truck in an attempt to reduce handling stress. As mentioned previously, tag codes were mixed during transport and therefore fish were not kept in separate net pens by distinct tag codes.

Table 4-3. Smolt Condition characteristics assessed for short term survival studies

Character	Normal	Abnormal
Percent Scale loss	lower relative numbers based on 0-100%	Higher relative number based on 0-100%
Body Color	High contrast dark dorsal surface and light sides	low contrast dorsal surface and sides, coppery color
Fin Hemorrhaging	No bleeding at base of fins	Blood present at base of fins
Eyes	Normally shaped	Bulging or with hemorrhaging
Gill Color	Dark beet red to cherry red colored gill filaments	Gray to light red colored gill filaments
Vigor	Active swimming (prior to anesthesia)	lethargic or motionless (prior to anesthesia)

Once placed into the pens, sub-samples of 25 fish from each pen were examined for swimming vigor then euthanized for measuring and documenting general condition of transported fish. Each fish was measured for fork length (to nearest 1 mm), weighed (to the nearest 0.1 g) and examined qualitatively for percent scale loss, body color, fin hemorrhaging, eye quality, and gill coloration. For the purposes of the 2005 VAMP study, Table 4-3 defines normal and abnormal conditions for these characteristics. Additionally, quality of adipose fin clip was documented. The sub-sampled fish were taken to the U.S. Fish and Wildlife Service, Stockton office (STFWO), for verification of tag code. After 48-hours, an additional 25 fish from each pen were measured, weighed, and examined for condition, as described above. The remaining fish from each pen were examined for mortalities, euthanized, counted, measured, weighed, and returned to STFWO for later tag code verification, if necessary.

Post transport fish were generally in good condition (Appendix A, Table A-2). All fish were swimming vigorously before being euthanized. Mean scale loss ranged from 2% at the second Jersey Point release up to 12% at the second Durham Ferry release (average of all locations = 5%). Body color and gill color were normal for all fish examined. No fin hemorrhaging was detected in any of the fish. Only one salmon (2%) from the first Jersey Point release had eye hemorrhaging. No errant CWT codes were detected in the 2005 VAMP salmon sub-samples, therefore no additional CWT verification was completed. Adipose fins were completely removed from an average of 85% (range of 74% to 94%) of the CWT salmon.

Short-term survival (48-hours post-transport) was high (99.9%) with only three mortalities (all from the first release at Durham Ferry) within the net pens. Fish retained in the net pens for the 48-hour post release examination were swimming vigorously and generally in good condition (Appendix A, Table A-3). Mean scale loss was (6%) at each site and ranged from 3% to 9% after each of the 48-hour trials. Few fish from the first set of releases had abnormal body color: 4 % from Durham Ferry, 2% from Dos Reis, and 2% from Jersey Point. Abnormal body color was not detected for any of the salmon from the second set of releases. Only 2% of the fish from the first Jersey Point release had fin hemorrhaging. Abnormal eye quality was detected in 4% of the Dos Reis and 2% of the Jersey Point fish from the first release. Abnormal eye quality was detected in 2% of the fish from each of the second releases at Durham Ferry and Dos Reis. Pale gills were detected in 2% of the fish from the second Dos Reis release. No other fish had abnormal gill coloration. These data indicate that the fish used for the 2005 VAMP experiment were in good general condition initially and after 48 hours, and that handling, transport, and release should not have affected their survival.

Health and Physiology

Juvenile Chinook salmon from tagged lots used in the 2005 VAMP study, were brought from the MRFF to the U.S. Fish and Wildlife Service California-Nevada Fish Health Center (CA/NA FHC) six days prior to the first VAMP release and reared for 50 days at water temperatures similar to the San Joaquin River (14.5 °C to 19.6 °C). At the time of transport, a fish health inspection showed that the population was generally healthy but had a low prevalence of an early stage infection by the myxosporean parasite, *Tetracapsula bryosalmonae*. This parasite has been detected in Merced River salmon for several decades (Hederick et al., 1986) and causes Proliferative Kidney Disease (PKD). The level of clinical PKD, as demonstrated by a combined kidney lesion and anemia score, markedly increased starting at 29 days post-exposure (dpe). A total of 76 study salmon (27% cumulative mortality) died due to PKD beginning at 36 dpe through the final sample at 50 dpe. Time post-exposure and disease state correlated with a decline in both hematocrit and plasma magnesium as well as an elevation in circulating white blood cell number and plasma protein concentration. There was no observed PKD effect on time to exhaustion during a 120-minute swim challenge until 50 dpe. Smolt development measurements indicated that the study fish were in an advanced stage of smoltification. Similar to swim performance, saltwater adaptation was not impaired until 50 dpe.

In addition to examining 2005/VAMP salmon maintained at the CA/NV FHC, selected salmon recovered at Chipps Island were also examined for the presence of PKD. While in the field, CWT salmon were dissected to remove the kidney and make kidney imprints on glass slides. *Tetracapsula bryosalmonae* was observed in 40% (17 of 43) of the kidney imprints collected from VAMP salmon recovered in the Chipps Island trawl. From the laboratory experiments, severe disease was not detected until 29 dpe which was chronologically after the last VAMP coded wire tag recovery at Chipps Island on 27 May 2005. These results indicate that while PKD was prevalent in VAMP out-migrating salmon, it may not have reduced VAMP recoveries. However PKD could be a significant mortality factor for VAMP salmon smolts during their early seaward entry phase (past all VAMP recovery stations). A full report is available in Foott et al., (2005).

Coded-Wire Tag Recovery Efforts

Coded-wire tagged salmon were recaptured at Old River, Mossdale, Antioch, Chipps Island, and the Federal (Central Valley Project (CVP)) and State Water Projects (SWP). CWT salmon recovered in California Department of Fish and Game (DFG) Kodiak trawls at Old River and Mossdale are not discussed in this chapter. Juvenile Chinook salmon with an adipose fin clip caught at all of the sampling locations (except Old River and Mossdale) were sacrificed, labeled, and frozen for CWT processing by staff at STFOW. DFG Region 4 staff processed CWT fish from Old River and Mossdale.

CWT processing consists of dissecting each tagged fish to obtain the 1-mm cylindrical tag from the snout. Tags were then placed under a dissecting microscope and the numbers were read and recorded in a database and archived. All tags were read twice, with any discrepancies resolved by a third reader. All tags were archived for future reference. It should be noted that many CWT Chinook salmon are captured during the VAMP study; however some of these fish may be tagged for other studies and are not affiliated with the VAMP study. VAMP releases comprise a small portion of the total tagged salmon released in the Sacramento and San Joaquin system. In order to identify tags related to VAMP, it is necessary to read all recovered tags.

Antioch Recapture Sampling

Fish sampling was conducted in the vicinity of Antioch on the lower San Joaquin River using a Kodiak trawl. The Kodiak trawl has a graded stretch mesh, from 2-inch mesh at the mouth to ½-inch mesh at the cod-end. Its overall length is 65 feet, and the mouth opening is 6 feet deep and 25 feet wide. The net was towed between two skiffs, sampling in an upstream direction. Trawls were performed near the left bank, within the mid-channel, and near the right bank to sample for CWT salmon emigrating from the San Joaquin River. Each sample was approximately 20 minutes in duration.

All captured fish were transferred immediately from the Kodiak trawl to buckets filled with river water, where they were held for processing. Data collected during each trawl included: species identification and fork length for each fish captured, tow start time and duration, and location in the channel. Any fish mortalities or injuries were documented to comply with the Endangered Species Act permit requirements. Juvenile Chinook salmon with an adipose fin clip were retained for later CWT processing while other fish were released at a location downstream of the sampling site immediately after identification, enumeration, and measurement.

Sampling at Antioch began May 4 and continued through May 31. Each day between 5:30 a.m. and 9:00 p.m., anywhere from 6 to 30 tows were conducted. In all, 633 Kodiak trawl samples were collected, for a total of 12,528 tow minutes. During sampling, 5,127 unmarked juvenile Chinook salmon were captured; 248 salmon with a coded wire tag were collected, 97 from VAMP releases (Table 4-4) and 151 from other hatchery releases. In addition, 363 delta smelt, 12 unmarked steelhead, and 6 adipose fin clipped steelhead were caught during sampling.

Table 4-4 (11x17; inserted at end of chapter)

Chippis Island Recapture Sampling

Recovery efforts at Chippis Island were conducted using a mid-water trawl towed at the surface. The trawling net is 82 feet in length and has an opening that is 30 feet wide by 10 feet deep. Mesh size of the net is variable and ranges from 4-inch mesh at the mouth to 5/16-inch mesh at the cod end. To keep the mouth of the net open, the net has floating aluminum hydrofoils on the top bridles and has steel depressors and a weighted lead line attached to the bottom bridles.

For VAMP 2005 trawling was conducted twice per day, seven days per week from May 3, 2005 through June 11, 2005. In past studies, greater recoveries of juvenile Chinook salmon smolts have been reported during sunrise and sunset (Hanson Environmental, unpublished data), therefore, the first shift began during sunrise and the second shift was completed during sunset in an attempt to increase the recovery of juvenile Chinook salmon smolts and reduce the variability in survival indices. Each shift consisted of ten 20-minute tows conducted in the north, middle, and south sections of the channel parallel to the shore. After six weeks the majority of VAMP juvenile Chinook salmon smolts had migrated past Chippis Island, so sampling was subsequently reduced. Ten morning tows were continued seven days per week between June 12 and June 19; five days per week between June 20 and July 1; and three days per week after July 5.

All fish retained in the cod end of the net are placed in aerated water collected from the sample site. All juvenile Chinook salmon smolts with an adipose fin clip were labeled and retained for later CWT processing. All other fish were identified to species, and enumerated, and released. The fork length of each individual was measured to the nearest mm for most of the catch. As mentioned previously, some salmon were also processed in the field to determine if *T. bryosalmonae* were present. A total of 59 juvenile Chinook salmon with tag codes used in the VAMP 2005 study were recaptured at Chippis Island, with the majority having been released at

Jersey Point. During this same time period, the catch included 11,111 unmarked Chinook salmon; 628 CWT Chinook salmon from non-VAMP studies; 101 Delta smelt; 130 Sacramento splittail; 23 marked steelhead; and 21 unmarked steelhead.

CVP and SWP Salvage Recapture Sampling

CVP and SWP fish facilities salvage fish on a continuous basis. To estimate the total number of fish salvaged, sub-samples (raw salvage) are collected approximately every two hours. The number of marked salmon collected during the sub-sampling (raw salvage) is reported in Table 4-4. Expanded salvage is a calculation based on the raw salvage collected and the time sampled and provides an estimate of the total number of fish salvaged. Expanded salvage does not take into account the indirect loss of juvenile salmon smolts at the facilities as it does not include any loss associated with pre-screening predation, screening, handling, and trucking. Expanded CVP and SWP salvage estimates are also reported in Table 4-4.

During VAMP 2005, expanded salvage was greater than salvage from releases at Durham Ferry in 2004 (CVP = 84; SWP = 12). The increase in salvage for VAMP 2005 was not surprising since the HORB was not installed. The installation of HORB reduces the number of fish observed at the fish facilities. Only a few juvenile salmon smolts that were released at Dos Reis and no smolts released at Jersey Point were observed in the raw salvage. The low salvage of smolts released at Dos Reis was anticipated as these fish are released downstream of the Head of Old River on an outgoing tide and would not be expected to be drawn through Old River into the fish facilities. The Jersey Point releases are downstream of all connections to Old River, but are released on an ebb tide to facilitate disbursement. Though in past years a few salmon released at Jersey Point have been observed, they are generally not expected at the salvage facilities.

Transit Time

The recoveries of the VAMP smolts collected in 2005 were made at Antioch between May 5 and May 24 and over a similar time period at Chipps Island between May 5 and May 27 (Appendix A, Figures A-11 through A-22). Recoveries were made at the CVP and SWP fish facilities between May 3 and May 31 (Table 4-4), a few days earlier and later than at the other recovery locations. All recoveries were made prior to the end of the VAMP period.

VAMP Chinook Salmon CWT Survival

Survival Indices

Survival indices were calculated to estimate survival to Antioch and Chipps Island for marked salmon released at Durham Ferry, Dos Reis and Jersey Point. Survival indices (SI) were calculated using the formula:

$$SI = (R / (ER * T * W))$$

where: R is the number recovered, ER is the effective number released, T is the fraction of time sampled, and W is the fraction of channel width sampled.

The fraction of the channel width sampled at Chipps Island (0.00769) was calculated by dividing the net width (30 feet) by the estimated channel width (3,900 feet). The fraction of the channel width sampled at Antioch (0.01388) was calculated in the same manner, with the net width being 25 feet and the channel width being 1,800 feet. The fraction of time sampled at both

locations was calculated based on the number of minutes sampled between the first and last day of catching each particular tag code or group, divided by the total number of minutes in the time period. The fraction of time sampled for the VAMP 2005 release groups at Chipps Island was about 28%, while at Antioch it was about 37% (Table 4-4).

Survival indices were calculated for each tag code to provide a sense of the variability associated with the group survival index. To generate the group survival index, the recovery numbers and release numbers are combined for the tag codes within a release group.

Chinook Salmon Survival Estimates, and Differential and Combined Differential Recovery Rates

Survival is further put into context by estimating absolute survival estimates and combined differential recovery rates (CDRR). Absolute survival estimates and CDRRs should be more robust for comparing survival between groups, recovery locations, and years, since using ratios between upstream and downstream groups theoretically standardizes for differences in catch efficiency between recovery locations and years. As in past years, both estimates of absolute survival and CDRRs were calculated for CWT releases as part of VAMP 2005. An additional estimate of survival, differential recovery rates (DRR) was also used for recoveries made in the ocean fishery, two to four years following release, for groups released in past years. DRR are also used when only the Chipps Island recovery location was used, as was the case prior to 2000.

Absolute survival estimates (AS_i) are calculated by the formula:

$$AS_i = SI_u / SI_d$$

where: SI_u is the survival index of the upstream group (Durham Ferry or Dos Reis), SI_d is the survival index of the downstream group (Jersey Point) and i is either Antioch or Chipps Island.

Although referred to throughout this document as absolute survival estimates they are more aptly described as standardized or relative survival estimates.

The combined recovery rate (CRR) is estimated by the formula:

$$CRR = R_{C+A} / ER$$

where: R_{C+A} is the combined recoveries at Antioch and Chipps Island of a CWT group, and ER is the effective release number.

The combined differential recovery rate (CDRR) is calculated by the formula:

$$CDRR = CRR_u / CRR_d$$

where: CRR_u is the combined recovery rate for the upstream group (Durham Ferry, Mossdale or Dos Reis), and CRR_d is the combined recovery rate for the downstream group (Jersey Point).

The CDRR and DRR are other ways to estimate survival between the upstream and downstream release locations. It is similar to calculating absolute survival estimates, but does not expand estimates based on the fraction of the time and space sampled.

The CDRR and the absolute survival estimates should not be very different as (1) the fraction of the time sampled is similar between groups within a recovery location and (2) the fraction of space sampled at each recovery location is a constant. Neither would change the

relative differences between groups. However, combining the recovery numbers from Antioch and Chipps Island could result in different survival estimates between the two methods.

Variance and standard errors were calculated for the CDRR and DRRs based on the Delta method recommended by Dr. Ken Newman. Plus or minus two standard errors are roughly equivalent to the 95% confidence intervals around the estimate. Plus or minus one standard error equates to roughly the 68% confidence intervals for normally distributed data (Ken Newman, University of St. Andrews, Scotland, personal communication). In comparing survival between reaches, the confidence intervals were used to determine if CDRRs were significantly different from each other. If the 95% confidence intervals overlapped, CDRRs were not considered statistically different from each other. Confidence intervals using the lower level of confidence (68%) are also included.

Results

Individual and group survival indices to Antioch and Chipps Island of the CWT salmon released as part of VAMP 2005 are shown in Table 4-4. Survival indices have been reported to three significant digits, but we realize indices are not likely that precise. Survival indices were not corrected for the number of CWT fish recovered in DFG sampling at Mossdale or in Old River.

The survival indices were low and ranged between 0.013 and 0.063 for the Durham Ferry and Dos Reis groups using either recoveries at Antioch or Chipps Island. We would have expected the Dos Reis survival indices to be greater than those for the Durham Ferry groups, but this was not the case for the first group recovered at Chipps Island (Table 4-4). The group survival index to Chipps Island for the first Durham Ferry group was 0.063 and for the first Dos Reis group was 0.022. This result could be due to the low recovery numbers and inherent variability in the survival indices.

One compounding factor experienced in 2005, was the application of Komeen in Clifton Court Forebay on May 3, a day after our first Durham Ferry release. Komeen is a chemical herbicide containing copper that is known to be toxic to salmon (J. Stuart, NOAA Fisheries, personal communication). During the application period there were no flows into or out of Clifton Court Forebay for 48 hours (DWR, Delta Field Division, personal communication). The SWP exports directly out of Clifton Court Forebay. The first Durham Ferry released fish was observed at the CVP on May 3, indicating that some of the CWT fish released at Durham Ferry may have been diverted into Clifton Court Forebay before the gates were closed on May 3rd which in turn could have reduced their survival. The first Durham Ferry fish was not observed at the SWP until May 8th. Although the first group released at Durham Ferry did not have consistently lower survival indices, than the second Durham Ferry release, to Antioch and Chipps Island, it is uncertain whether this treatment lessened the survival of the first group released at Durham Ferry. We have requested further communication from DWR regarding the timing of when these herbicide applications are scheduled to avoid this potential problem in the future.

The control groups released at Jersey Point had greater survival than those fish released at Durham Ferry or Dos Reis. The survival index of the first Jersey Point group was 0.263 at Antioch and 0.634 at Chipps Island. The second Jersey Point release had survival indices of 0.212 at Antioch and 0.711 at Chipps Island.

In general, higher survival indices were estimated using the Chipps Island recoveries. As in past years, the raw recovery rate at Chipps Island and Antioch was similar, but once recoveries were expanded for effort, indices indicated that recoveries were much lower at Antioch, indicating that the greater sampling at Antioch is not translating into additional recoveries.

Survival indices for releases made at Durham Ferry and Dos Reis were low relative to releases made at Jersey Point using either set of recovery numbers (Table 4-4). This is especially clear when looking at absolute survival rates and CDRR's (Table 4-5).

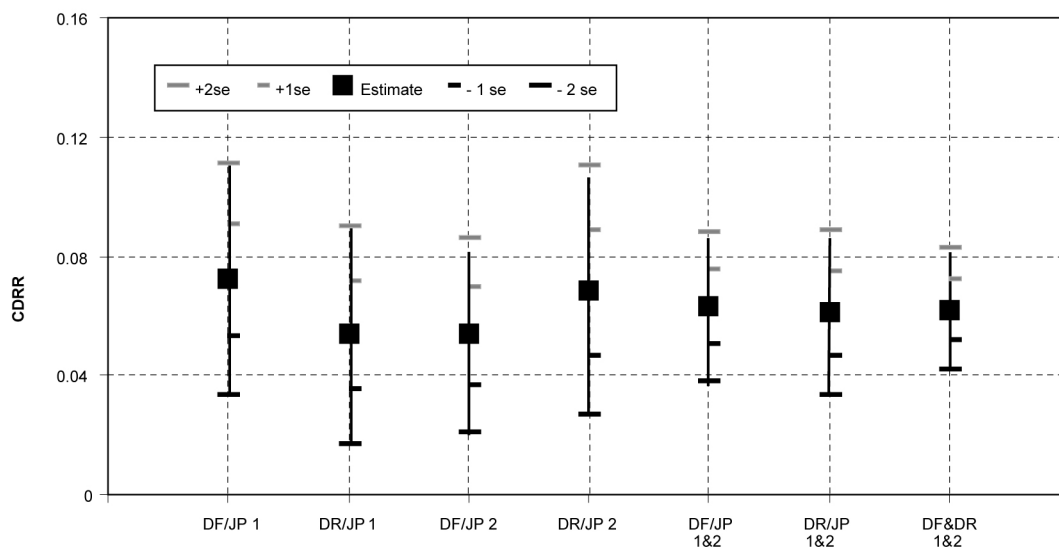
The CDRR's for the Durham Ferry groups relative to the Jersey Point groups were 0.069 and 0.051 for the first and second releases, respectively. The Dos Reis to Jersey Point CDRR estimates were 0.052 for the first and 0.068 for the second release (Table 4-5). Confidence intervals around each of the estimates suggested estimates were not significantly different for the two groups even though fish released at Durham Ferry are thought to incur additional mortality since it is roughly 15 miles farther upstream than Dos Reis and there was no HORB (Figure 4-5).

The pooled CDRRs of the two Dos Reis groups was 0.060. The pooled CDRR of the Durham Ferry groups was also 0.060. Further pooling of both sets resulted in the CDRR being 0.060. Plus and minus one and two standard errors of the estimates were also calculated and are shown in Figure 4-5.

Table 4-5. Absolute survival and Combined Differential Recovery Rates (CDRR) for VAMP releases in 2005

Survival Reach	Release Date	Antioch Absolute Survival	Chipps Island Absolute Survival	CDRR
First release				
Durham Ferry to Jersey Point	2-May-05	0.049	0.099	0.069
Dos Reis to Jersey Point	3-May-05	0.11	0.035	0.052
Second release				
Durham Ferry to Jersey Point	9-May-05	0.094	0.044	0.051
Dos Reis to Jersey Point	10-May-05	0.127	0.058	0.068

Figure 4-5. Combined Differential Recovery Rates (CDRR) (+/- 1 and 2 standard errors) of CWT smolts released at Durham Ferry (DF/JP) and Dos Reis (DR/JP) relative to those released at Jersey Point for the first (1), second (2) and combined release groups (1 and 2) in 2005.



Comparison with Past Years

Ocean Recovery Information

Ocean recovery data of CWT salmon groups can provide another independent estimate of the ratio of recovery rate of an upstream release group relative to a downstream release group. Differential recovery rates using ocean recovery information can be compared with absolute survival estimates based on survival indices and the differential (DRR) or combined differential recovery rates (CDRR) of juvenile salmon recovered at Chipps Island and Chipps Island and Antioch, respectively. The ocean data may be more reliable due to the number of CWT recoveries and the extended recovery period.

Adult ocean recovery data are gathered from commercial and sport ocean harvest checked at various ports by DFG. The Pacific States Marine Fisheries Commission database of ocean harvest CWT data was the source of recoveries through 2004. The ocean CWT recovery data accumulate over a one to four year period after the year a study release is made as nearly all of a given year-class of salmon have been either harvested or spawned by age five. Consequently, these data are essentially complete for releases made through 2000 and partially available for CWT releases made from 2001 to 2003.

Differential recovery rates based on ocean recoveries, Chipps Island recoveries or combined Antioch and Chipps Island recoveries for salmon produced at the MRFF are shown in Table 4-6. Absolute survival estimates based on Chipps Island and Antioch survival indices are also included. The earlier releases were made as part of south Delta survival evaluations (1996-1999) with the later releases associated with VAMP (2000-2003). Releases have been made at several locations: Durham Ferry, Mossdale, Dos Reis, and Jersey Point. The Chipps Island and Antioch survival estimates and CDRR (Antioch and Chipps Island recoveries summed) or DRR (Chipps Island recoveries only) are graphed in relation to the differential recovery rate using the ocean recovery information in Figure 4-6.

Results of this comparative analysis of survival estimates and differential recovery rates for Chinook salmon produced in the MRFF show: (1) there is general agreement between absolute survival estimates based on juvenile CWT salmon recoveries at Chipps Island and the DRR or CDRR using recoveries at Chipps Island or Chipps Island and Antioch and the DRR using adult recoveries from the ocean fishery ($r^2=0.71$ and $r^2 = 0.67$), (2) there is less agreement with Antioch trawling which has fewer years of data, and (3) additional comparisons need to be made, as more data becomes available from VAMP releases for recoveries at Antioch, Chipps Island, and the ocean fishery.

Table 4-6. Survival indices based on Chipps Island, Antioch, and ocean recoveries of Merced River Fish Facility salmon released as part of South Delta studies (1996 - 1999) and VAMP (2000 - 2003)

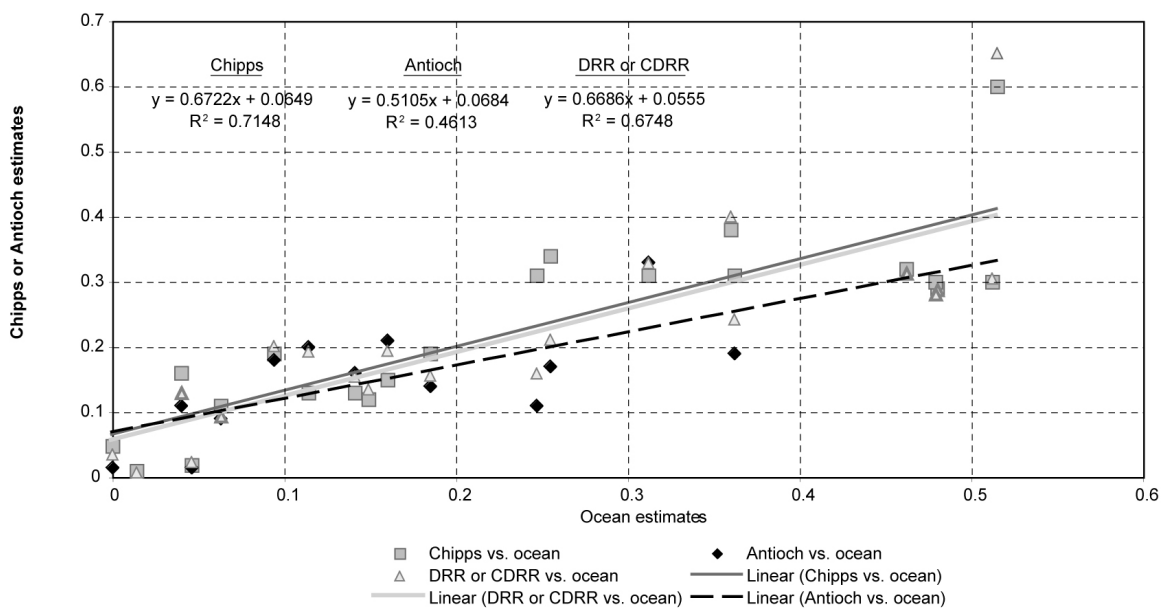
Release Year	San Joaquin River (Merced River origin) Tag Number	Release Number	Release Site	Release Date	Chippis Island Recovs.	Antioch Recovs.	Expanded Adult Ocean Recovs.	Chippis Island	Antioch	DRR or CDRR	Ocean Catch		
		Juvenile Salmon CWT Releases					(Age 1+ to 4+) Total					Absolute Survival Estimates	Differential Recovery Rates
1996	H61110412	25,633	DOS REIS	01MAY96	2		3						
	H61110413	28,192	DOS REIS	01MAY96	3		37						
	H61110414	18,533	DOS REIS	01MAY96	1		8						
	H61110415	36,037	DOS REIS	01MAY96	5		10						
	H61110501	53,337	JERSEY PT	03MAY96	39		187						
	Effective Release	107,961	DOS REIS		11		58	0.120		0.135	0.149		
	Effective Release	51,737	JERSEY PT		39		187						
1997	H62545	50,695	DOS REIS	29APR97	9		183						
	H62546	55,315	DOS REIS	29APR97	7		167						
	H62547	51,588	JERSEY PT	02MAY97	27		355						
	Effective Release	106,010	DOS REIS		16		350	0.290		0.288	0.480		
	Effective Release	51,588	JERSEY PT		27		355						
	H62548	46,728	DOS REIS	08MAY97	5		91	0.300		0.281	0.479		
	H62549	47,254	JERSEY PT	12MAY97	18		192						
1998	61110809	26,465	MOSSDALE	16APR98	25		61						
	61110810	25,264	MOSSDALE	16APR98	31		40						
	61110811	25,926	MOSSDALE	16APR98	32		58						
	61110806	26,215	DOS REIS	17APR98	33		47						
	61110807	26,366	DOS REIS	17APR98	23		35						
	61110808	24,792	DOS REIS	17APR98	34		61						
	61110812	24,598	JERSEY PT	20APR98	87		110						
	61110813	25,673	JERSEY PT	20APR98	100		91						
	Effective Release	77,655	MOSSDALE		88		159	0.300		0.305	0.512		
	Effective Release	77,373	DOS REIS		90		143	0.320		0.313	0.462		
Effective Release	50,271	JERSEY PT		187		201							
1999	062642	24,715	MOSSDALE	19APR99	8		128						
	062643	24,725	MOSSDALE	19APR99	15		134						
	062644	25,433	MOSSDALE	19APR99	13		132						
	062645	25,014	DOS REIS	19APR99	20		151						
	062646	24,841	DOS REIS	19APR99	19		225						
	0601110815	24,927	JERSEY PT	21APR99	34		338						
	062647	24,193	JERSEY PT	21APR99	25		381						
	Effective Release	74,873	MOSSDALE		36		394	0.380		0.400	0.360		
	Effective Release	49,855	DOS REIS		39		376	0.600		0.651	0.515		
	Effective Release	49,120	JERSEY PT		59		719						
2000	06-45-63	24,457	DURHAM FERRY	17-Apr-00	11	11	245						
	06-04-01	23,529	DURHAM FERRY	17-Apr-00	7	6	214						
	06-04-02	24,177	DURHAM FERRY	17-Apr-00	10	10	229						
	06-44-01	23,465	MOSSDALE	18-Apr-00	9	14	206						
	06-44-02	22,784	MOSSDALE	18-Apr-00	9	16	174						
	06-44-03	25,527	JERSEY PT	20-Apr-00	24	50	646						
	06-44-04	25,824	JERSEY PT	20-Apr-00	41	47	706						
	Effective Release	72,163	DURHAM FERRY		28	27	688	0.310	0.190	0.242	0.362		
	Effective Release	46,249	MOSSDALE		18	30	380	0.310	0.330	0.329	0.312		
	Effective Release	51,351	JERSEY PT		65	97	1352						
	601060914	23,698	DURHAM FERRY	28-Apr-00	7	8	46						
	601060915	26,805	DURHAM FERRY	28-Apr-00	5	15	44						
	0601110814	23,889	DURHAM FERRY	28-Apr-00	10	8	70						
	0601061001	25,572	JERSEY PT	1-May-00	48	76	356						
	0601061002	24,661	JERSEY PT	1-May-00	30	76	228						
	Effective Release	74,392	DURHAM FERRY		22	31	160	0.190	0.140	0.156	0.185		
Effective Release	50,233	JERSEY PT		78	152	584							
2001	06-44-29	23,354	DURHAM FERRY	30-Apr-01	14	28	95						
	06-44-30	22,837	DURHAM FERRY	30-Apr-01	22	30	155						
	06-44-31	22,491	DURHAM FERRY	30-Apr-01	17	18	110						
	06-44-32	23,000	MOSSDALE	1-May-01	17	18	123						
	06-44-33	22,177	MOSSDALE	1-May-01	14	15	107						
	06-44-34	24,443	JERSEY PT	4-May-01	50	156	464						
	06-44-35	24,992	JERSEY PT	4-May-01	61	173	553						
	Effective Release	68,682	DURHAM FERRY		53	76	360	0.340	0.170	0.211	0.255		
	Effective Release	45,177	MOSSDALE		31	33	230	0.310	0.110	0.159	0.247		

Table 4-6 (cont.). Survival indices based on Chipps Island, Antioch, and ocean recoveries of Merced River Fish Facility salmon released as part of South Delta studies (1996 - 1999) and VAMP (2000 - 2003)

Release Year	San Joaquin River (Merced River origin) Tag Number	Release Number	Release Site	Release Date	Chipps Island Recovs.	Antioch Recovs.	Expanded Adult Ocean Recovs. (Age 1+ to 4+) Total	Chipps Island	Antioch	DRR or CDRR	Ocean Catch
								Absolute Survival Estimates	Differential Recovery Rates		
	Effective Release	49,435	JERSEY PT		111	329	1017				
	06-44-36	24,025	DURHAM FERRY	7-May-01	2	8	17				
	06-44-37	24,029	DURHAM FERRY	7-May-01	5	11	47				
	06-44-38	24,177	DURHAM FERRY	7-May-01	2	10	28				
	06-44-39	23,878	MOSSDALE	8-May-01	4	8	25				
	06-44-40	25,308	MOSSDALE	8-May-01	4	11	27				
	06-44-41	25,909	JERSEY PT	11-May-01	17	43	243				
	06-44-42	25,465	JERSEY PT	11-May-01	27	53	332				
	Effective Release	72,231	DURHAM FERRY		9	29	92	0.130	0.200	0.193	0.114
	Effective Release	49,186	MOSSDALE		8	19	52	0.190	0.180	0.201	0.094
2002	Effective Release	51,374	JERSEY PT		44	96	575				
	06-44-71	23,920	DURHAM FERRY	18-Apr-02	4	11	30				
	06-44-72	25,176	DURHAM FERRY	18-Apr-02	9	20	84				
	06-44-73	23,872	DURHAM FERRY	18-Apr-02	4	12	65				
	06-44-74	24,747	DURHAM FERRY	18-Apr-02	4	20	61				
	06-44-57	25,515	MOSSDALE	19-Apr-02	6	13	72				
	06-44-58	25,272	MOSSDALE	19-Apr-02	7	29	70				
	06-44-59	24,802	JERSEY PT	22-Apr-02	46	101	461				
	06-44-60	24,128	JERSEY PT	22-Apr-02	37	89	394				
	Effective Release	97,715	DURHAM FERRY		21	63	240	0.130	0.160	0.154	0.141
2002	Effective Release	50,787	MOSSDALE		13	42	142	0.150	0.210	0.194	0.160
	Effective Release	48,930	JERSEY PT		83	190	855				
	06-44-70	24,680	DURHAM FERRY	25-Apr-02	3	6	18				
	06-44-75	24,659	DURHAM FERRY	25-Apr-02	5	2	17				
	06-44-76	24,783	DURHAM FERRY	25-Apr-02	3	4	8				
	06-44-77	24,381	DURHAM FERRY	25-Apr-02	4	6	4				
	06-44-78	24,519	MOSSDALE	26-Apr-02	2	3	23				
	06-44-79	24,820	MOSSDALE	26-Apr-02	3	4	14				
	06-44-80	24,032	JERSEY PT	30-Apr-02	18	43	282				
	06-44-81	22,880	JERSEY PT	30-Apr-02	28	32	278				
2002	Effective Release	98,503	DURHAM FERRY		15	18	47	0.160	0.110	0.130	0.040
	Effective Release	49,339	MOSSDALE		5	7	37	0.110	0.090	0.094	0.063
	Effective Release	46,912	JERSEY PT		46	75	560				
	06-02-82	24,563	DURHAM FERRY	21-Apr-03	0	1	5				
	06-02-83	26,036	DURHAM FERRY	21-Apr-03	2	4	0				
	06-27-42	24,179	DURHAM FERRY	21-Apr-03	1	1	8				
	06-27-48	24,706	MOSSDALE	22-Apr-03	2	2	0				
	06-27-43	25,480	MOSSDALE	22-Apr-03	3	2	0				
	06-27-44	24,649	JERSEY PT	25-Apr-03	57	71	93				
	Effective Release	74,778	DURHAM FERRY		3	6	13	0.019	0.015	0.023	0.046
2003	Effective Release	50,186	MOSSDALE		5	4	0	0.048	0.015	0.035	0.000
	Effective Release	24,649	JERSEY PT		57	71	93				
	06-27-45	24,815	DURHAM FERRY	28-Apr-03	0	0	0				
	06-27-46	25,319	DURHAM FERRY	28-Apr-03	0	0	0				
	06-27-47	24,758	DURHAM FERRY	28-Apr-03	0	0	0				
	06-27-49	24,219	MOSSDALE	29-Apr-03	0	0	3				
	06-27-50	24,505	MOSSDALE	29-Apr-03	1	0	0				
	06-27-51	25,950	JERSEY PT	2-May-03	39	36	115				
	Effective Release	74,892	DURHAM FERRY		0	0	0			0.000	0.000
	Effective Release	48,724	MOSSDALE		1	0	3	0.010		0.007	0.014
2003	Effective Release	25,950	JERSEY PT		39	36	115				

Note: Ocean recoveries are based on data through 2004.

Figure 4-6. Comparison of Antioch and Chipps Island absolute survival estimates and differential or combined differential recovery rates compared to differential ocean recovery rates for 1996-2003



Survival by Reach

In this section, Chinook salmon smolt survival in different reaches of the San Joaquin River will be evaluated between years. These analyses help our understanding of survival through the Delta for VAMP. Initially, survival in the entire reach (Durham Ferry or Mossdale to Jersey Point) will be discussed. Then the entire reach will be broken down by section and discussed further. The second reach discussed will be between Durham Ferry and Mossdale. The third reach is between Durham Ferry (or Mossdale) and Dos Reis. And lastly, the reach between Dos Reis and Jersey Point will be discussed. In this section we will only use CDRR or DRR as our estimate of survival. Data gathered prior to 2000 do not have any Antioch recoveries thus DRR's have been calculated using Chipps Island recoveries alone.

Survival between Durham Ferry or Mossdale and Jersey Point

Smolt survival between Durham Ferry and Jersey Point was low in 2005, as it was in 2003 and 2004. The 2005 survival estimates (0.07 and 0.05) were higher than those obtained in 2003 (0.023, and 0.0) and 2004 (0.026), but still low. The confidence intervals indicate that pooled survival between 2005 and 2004 was not significantly different (Figure 4-7). The pooled estimate in 2003 was the lowest measured to date with a HORB in place. Both the 2003 and 2004 data were much lower than other VAMP years (with the HORB in place) which started in 2000 (Table 4-7). The 2005 data was greater than that gathered in 1994 (0.0) when the HORB was not installed.

The health of the CWT fish in 2005 may account for some of the low survival observed in 2005. While the fish appeared healthy at the hatchery prior to release, they had a low level of PKD infection. The disease progressed in test fish taken back to the CA/NV Fish Health Center, with severe occurrence observed after 29 days. Forty percent of the VAMP fish recovered at Chipps Island had evidence of infection in their kidneys by the parasite that causes PKD. It is not clear whether these levels of low initial infection rates may have affected our survival estimates

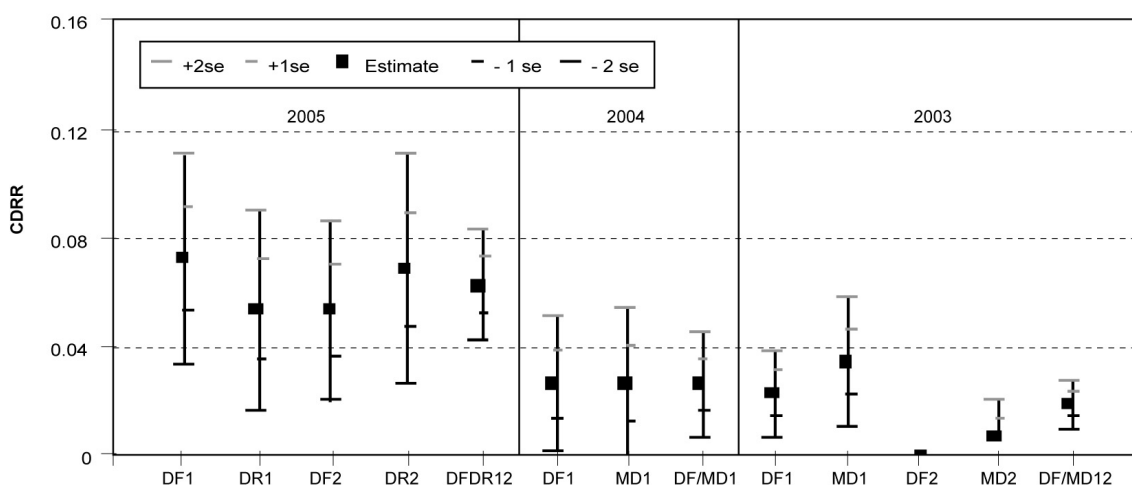
to Antioch and Chipps Island in 2005. The CA/NV Fish Health Center concluded that while PKD in the VAMP fish may not have affected their survival to Chipps Island it may affect their long-term survival.

In 2003 and 2004, VAMP experimental fish also had PKD. We hypothesized that the PKD alone did not cause the higher mortality since infection and severe infection rates were not as high as they had been in 2001 when survival was greater (SJRG, 2005). However, the high level of PKD infection in combination with the lower flows in 2003 and 2004 may have differentially increased the mortality of upstream released VAMP fish since Jersey Point groups also had PKD but survived at a higher rate. This hypotheses seems supported by the work conducted by the CA/NV FHC in 2005, that indicated that PKD infection and its effects get worse over time and that a longer migration period (due to the lower flows and further distance than those released at Jersey Point) could have resulted in less smolts surviving to Chipps Island in 2003 and 2004.

Table 4-7. Pooled, Combined Differential Recovery Rate (CDRR) and standard errors for CWT salmon released at Mossdale, Dos Reis and Durham Ferry in relation to those released at Jersey Point between 2000 and 2005

Year	CDRR	Standard Error
2000	0.187	0.019
2001	0.191	0.014
2002	0.151	0.013
2003	0.019	0.005
2004	0.026	0.010
2005	0.060	0.010

Figure 4-7. Combined Differential Recovery Rates (CDRR) (+ / - 1 and 2 standard errors) of CWT smolts released at Durham Ferry (DF), Mossdale (MD) and Dos Reis (DR) relative to those released at Jersey Point for the first (1), second (2) and combined release groups in 2003, 2004 and 2005. Only one set of releases was made in 2004.



Survival between Durham Ferry and Mossdale

No releases were made at Mossdale in 2005 thus comparisons of survival rates between Durham Ferry and Mossdale cannot be made. However, survival between Durham Ferry and Mossdale between 2000 and 2004 has been generally high using both the Chipps Island and Antioch recoveries as well as the ocean recoveries (Table 4-8). Releases of marked fish at both

sites will allow detection of mortality between Durham Ferry and Mossdale if mortality becomes great enough to detect in the future.

Table 4-8. Combined Differential Recovery Rates and Differential Recovery Rates for recoveries at Chipps and Antioch and in the ocean fishery for VAMP fish released at Durham Ferry and Mossdale between 2000 and 2004

Year	CDRR Chipps and Antioch	DRR Ocean
2000	0.733	1.17
2001	1.325	1.04
2001	0.958	1.19
2002	0.794	0.93
2002	1.377	0.65
2003	0.667	
2003	0	
2004	0.998	

Survival between Durham Ferry (or Mossdale) and Dos Reis

In 2005, releases were made at Durham Ferry and Dos Reis. However, the differences in survival between the two sites and Jersey Point in 2005 were not consistently or significantly different from each other (Figure 4-5). In past years, releases have also been made at Dos Reis and prior to 2005, were paired with comparable releases at Mossdale without the HORB in place. Average survival between Mossdale or Durham Ferry and Dos Reis was 0.71 using the Chipps Island recoveries (and Antioch recoveries in 2005) whereas it was 0.65 using the ocean recoveries (Table 4-9). However, there were two out of the nine instances using the Chipps Island recoveries and one instance using the ocean recoveries where the Mossdale or Durham Ferry groups survived at a higher rate than the Dos Reis groups. Low recovery rates, especially at Chipps Island and Antioch, may hinder our ability to consistently see differences even if they do exist.

Only once were releases made at Mossdale and Dos Reis with the HORB in place. That was in 1997 and estimates of survival between the two locations were 1.02 using Chipps Island recoveries and 1.29 using ocean recoveries. These data further reinforce that the temporary HORB provides protection to juvenile salmon migrating from the San Joaquin basin by reducing or preventing these fish from being drawn into upper Old River.

Table 4-9. Differential Recovery Rates (and Combined Differential Recovery Rates in 2005) for experimental fish released at Mossdale (or Durham Ferry) and Dos Reis between 1995 and 2005

MD/DF- DR	Release Date	CI	Ocean
1995	17-Apr	1.26	0.99
1995	5-May	0.31	0.51
1995	17-May	0.44	0.71
1996	30-Apr	0.33	0.38
1998	16-Apr	0.94	1.07
1998	23-Apr	0.4	0.22
1999	19-Apr	0.62	0.7
2005	2-May	1.36	
2005	9-May	0.76	
Average		0.71	0.65

Table 4-10. CDRR and DRR for survival between Dos Reis (DR) and Jersey Point (JP) between 1989 and 2005. Stock is either Feather River (FR) or Merced River (MR). The HORB was usually not installed (n) except in 1997 (y).

Year	Release Date	CI DRR or CI and Antioch CDRR	Stock	HORB	DRR Ocean
1989	20-Apr	0.16	FR	n	0.2
1990	16-Apr	0.06	FR	n	0.05
1990	2-May	0.03	FR	n	0.08
1991	15-Apr	0.09	FR	n	0.13
1995	17-Apr	0.31	FR	n	0.83
1996	1-May	0.06	FR	n	0.11
1996	1-May	0.12	MR	n	0.15
1998	17-Apr	0.32	MR	n	0.47
1998	24-Apr	0.28	FR	n	0.77
1999	19-Apr	0.66	MR	n	0.52
1997	29-Apr	0.18	FR	y	0.37
1997	29-Apr	0.3	MR	y	0.492
1997	8-May	0.28	MR	y	0.485
2005	3-May	0.05	MR	n	
2005	10-May	0.07	MR	n	
Average		0.20			0.36

Survival between Dos Reis and Jersey Point

Survival in the reach from Dos Reis to Jersey Point in 2005 was much lower than survival from Durham Ferry to Dos Reis. This indicates that most of the juvenile salmon mortality occurs in the lower reach of the Delta. This finding is consistent in all years.

There have been 15 experiments where releases have been made at Dos Reis and Jersey Point, with three of these made in 1997 with the HORB in place. Data was gathered in the spring between 1989 and 1991, 1995 and 1999 and during 2005 without the HORB in place. Survival for the non-HORB years, using CDRR or DRR at Chipps Island (and Antioch recoveries in 2005) ranged between 0.03 and 0.66 and averaged 0.20. For ocean recoveries the DRR ranged between 0.05 and 0.83 and averaged 0.36 (Table 4-10). These data indicate that survival from Dos Reis to Jersey Point is generally low but has been relatively high some years. The highest survival was observed in 1995, 1997, 1998 and 1999.

The Role of Flow, Exports and the Head of Old River Barrier on Smolt Survival Through the Delta

San Joaquin River flow and flow relative to exports between April 15 and June 15 was correlated to adult escapement in the San Joaquin basin 2 ½ years later (SJRG 2003). Both relationships were statistically significant ($p < 0.01$) with the ratio of flow to exports accounting for slightly more of the variability in escapement than flow alone ($r^2 = 0.58$ versus $r^2 = 0.42$; SJRG 2003). These relationships suggest that adult escapement in the San Joaquin basin is affected by flow in the San Joaquin River at Vernalis and exports by the CVP and SWP during the spring

months when juveniles migrate through the river and Delta to the ocean. These relationships serve as conceptual models of how smolt survival would vary with flows and exports.

VAMP was designed to further define these relationships by testing how San Joaquin River flows (7,000 cfs or less) at Vernalis and exports (1,500 to 3,000 cfs) at SWP and CVP, with the HORB, affect smolt survival through the Delta. The HORB is assumed to improve survival based on studies conducted between 1985 and 1990 (Brandes and McLain, 2001). These studies indicated that smolts released on the San Joaquin River downstream of the HOR survived at about twice the rate of those released in the Old River. And while those data were not statistically significant, placing a temporary barrier at the Head of Old River appeared to be a management action that would improve survival through the Delta for smolts originating from the San Joaquin basin. The HORB barrier cannot be installed when the San Joaquin River flows exceed 5,000 cfs during the scheduled installation period, and would potentially need to be removed if the San Joaquin River flows were to exceed 7,000 cfs.

Survival of juvenile Chinook salmon emigrating from the San Joaquin River system has been evaluated within the framework established by the VAMP since the spring of 2000. The installation of the HORB is assumed as part of the VAMP experimental design. This year was the first year since 2000 that the HORB has not been in place during the VAMP experiment. However, similar survival tests both with and without the HORB were conducted prior to 2000. The results of these earlier tests were also used to help define the relationships between flow and exports on smolt survival with and without the HORB in place.

Role of Flow on Salmon Survival

To assess the relationship between San Joaquin River flows at Vernalis and smolt survival with and without the HORB, CDRRs using recoveries at Chipps Island and Antioch as our estimate of survival between Durham Ferry and Mossdale and Jersey Point data from 1994-2005 were plotted. In the past the CDRRs of all Durham Ferry and Mossdale releases within a year were pooled, as they were not significantly different from each other at the 95% confidence level. To increase our sample size, each separate estimate was used in this year's evaluation. Prior to combining the data from both locations, regression lines comparing the CDRR/ DRR's to Vernalis flow were evaluated from both locations independently. The results indicated that the variances and the regression lines from the two locations were not statistically different. Thus the CDRR/DRR data from both Mossdale and Durham Ferry releases were plotted together in the various relationships discussed below.

Flows at Vernalis were 10 day averages for each release starting on the day of the Mossdale release (in previous years) or the day after the Durham Ferry release. Ten day averages were used to represent the flow variable since after 10 days most of the fish are far enough downstream (with some already recovered) that the flow at Vernalis is probably no longer important for that particular group migrating to Chipps Island. Flow data was obtained through DWR's DAYFLOW for past years (updated January 2004). San Joaquin flows downstream of Old River prior to 2005 were obtained from DWR from a model that simulated historical flows using DSM2 (T. Smith, DWR Personal Communication). A request has been made to DWR to compare measured flows to those predicted by the model for the spring of 2005.

Role of Flow with HORB on Salmon Survival

The CDRR/DRRs using the Chipps Island and Antioch recoveries of the Mossdale and Durham Ferry groups relative to the Jersey Point groups did increase with Vernalis flow with the HORB in place ($p < 0.01$; Figure 4-8).

The relationship between Vernalis flow and DRR using the ocean data with the HORB was also positive and statistically significant ($p < 0.01$; Figure 4-9). The ocean data has fewer data points because recoveries are not yet available for the 2004 and 2005 releases.

Figure 4-8. CDRR or DRR using Chipps Island and Antioch recoveries between Mossdale or Durham Ferry and Jersey Point with the HORB in place and average flow at Vernalis in cfs for 10 days starting the day of the Mossdale release or the day after the Durham Ferry release

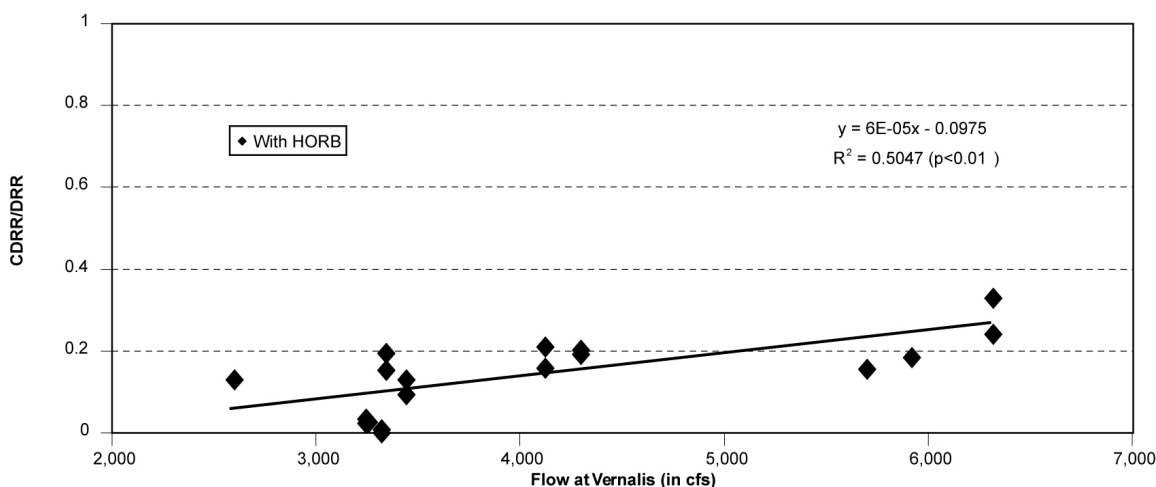
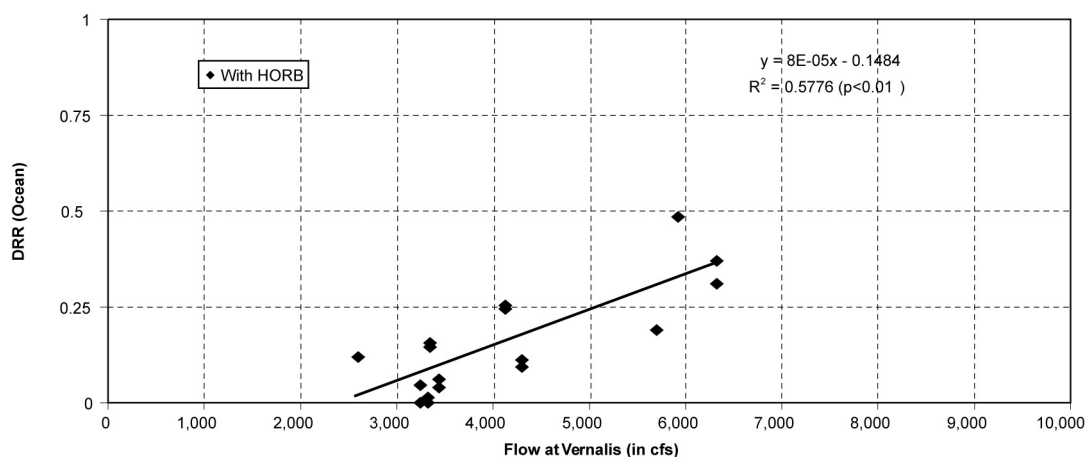


Figure 4-9. DRR using ocean recoveries, between Mossdale or Durham Ferry and Jersey Point and average flow at Vernalis in cfs for 10 days starting the day of the Mossdale release or the day after the Durham Ferry release with the HORB in place



Role of Flow without HORB on Salmon Survival

Without the HORB in place, the regression line of the DRR/ CDRR's using the Chipps Island and Antioch recoveries of the Mossdale and Durham Ferry to Jersey Point survival increased with flow, but the relationship was not statistically significant (Figure 4-10).

The relationship using the ocean data without the HORB had a higher r^2 value than the one obtained using the Chipps Island and Antioch data, but was still not statistically significant (Figure 4-11). The two relationships were similar indicating that increasing flow may improve

survival of the Mossdale and Durham Ferry groups relative to the Jersey Point groups without the HORB in place.

It is not surprising that there is more variability associated with smolt survival at any given flow at Vernalis without the HORB since the flow and proportion of marked fish moving into HOR varies more without the HORB.

To explore this issue further, we evaluated a group of test fish that “stayed” on the mainstem San Joaquin River and were not diverted into upper Old River. The CDRR/ DRR’s of smolts released at Dos Reis relative to those released at Jersey Point were compared to modeled San Joaquin flow downstream of the HOR. Three data points were gathered when the HORB was installed in 1997. The Chipps Island/Antioch data indicated a possible relationship between survival and flow, but one year (1999) was an obvious outlier (Figure 4-12). The relationship using the ocean recovery data showed that survival from Dos Reis to Jersey Point did increase with San Joaquin flows downstream of the HOR and it was statistically significant at the $p < 0.01$ level (Figure 4-13). The 1999 data was no longer an outlier indicating that perhaps the Jersey Point group was biased low due to some missed sampling at Chipps Island that spring, as hypothesized in an earlier report (Brandes, 2000). This relationship indicated that survival is increased as flow increases on the mainstem San Joaquin River downstream of Old River, for the fish staying on the mainstem San Joaquin River when there is no HORB in place.

Figure 4-10. CDRR or DRR using Chipps Island and Antioch recoveries between Mossdale or Durham Ferry and Jersey Point and average flow at Vernalis in cfs for 10 days starting the day of the Mossdale release or the day after the Durham Ferry release without the HORB in place

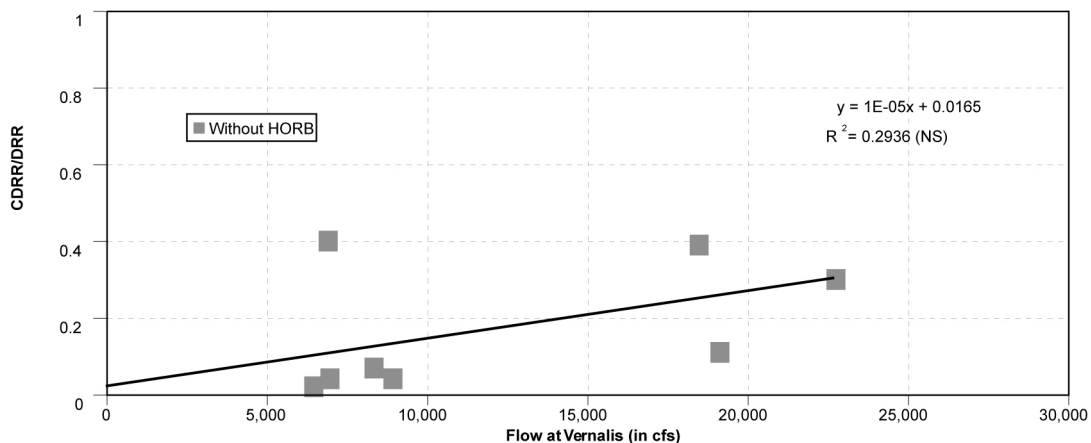


Figure 4-11. DRR using ocean recoveries, between Mossdale or Durham Ferry and Jersey Point and average flow at Vernalis in cfs for 10 days starting the day of the Mossdale release or the day after the Durham Ferry release with and without the HORB in place

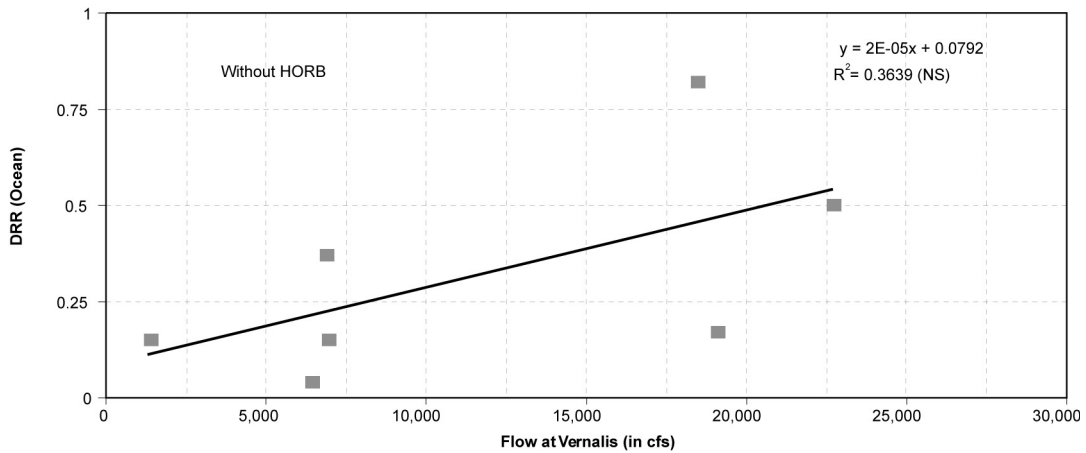


Figure 4-12. Survival between Dos Reis and Jersey Point (using recoveries at Chipps or Chipps and Antioch) with and without the HORB and modeled San Joaquin flows downstream of Old River. 1997 data was gathered with the HORB in place

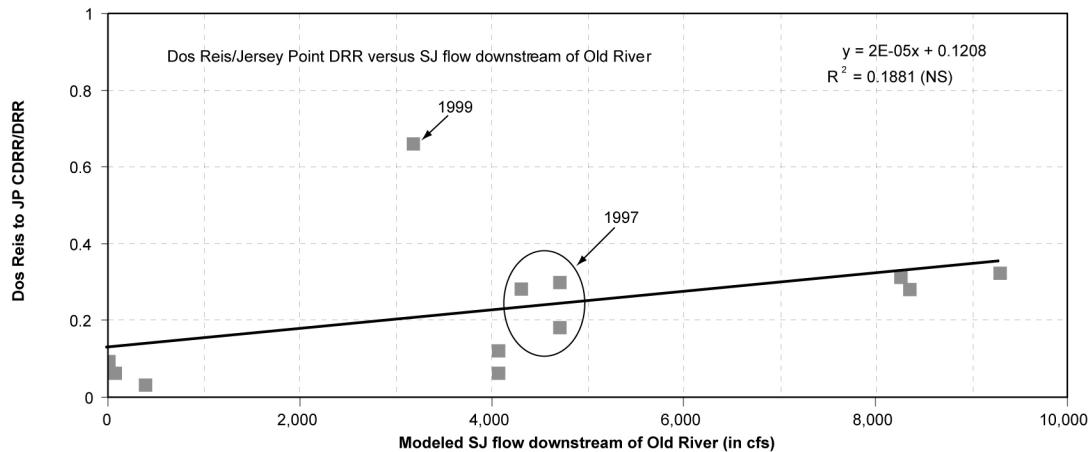
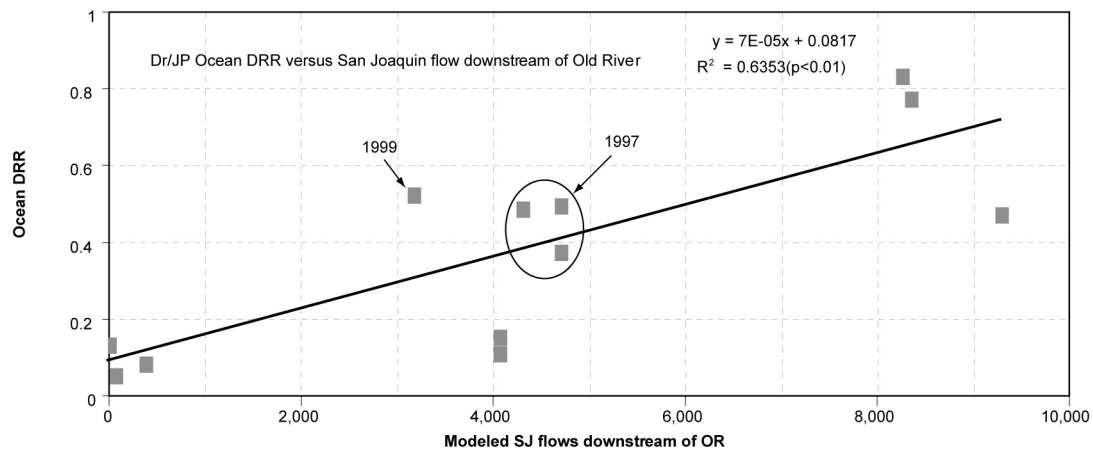


Figure 4-13. Ocean DRR of survival between Dos Reis and Jersey Point with and without a HORB and San Joaquin flows downstream of Old River. 1997 data was gathered with the HORB in place.



The Role of Exports on Survival

Another goal of the VAMP program is to identify the role of exports on juvenile salmon survival through the Delta. VAMP limits CVP+SWP exports to between 1,500 and 3,000 cfs depending on the flow target, because of its dual protective purpose. Historically, exports were generally much greater during this period. The VAMP design was intended to identify the role of exports with the HORB at flows of 7,000 cfs by experimenting at exports of 1,500 and 3,000 cfs. Conditions have not provided a 7,000 cfs flow with a HORB to test either export level. These limitations have made assessing the role of exports using the VAMP data difficult at this time.

In years when the HORB could not be installed it was recommended in the VAMP framework agreement to limit exports to either 1,500 or 3,000 cfs to make better comparisons with and without the HORB. In 2005, an agreement to have combined SWP/CVP pumping at 1,500 cfs for two weeks and then 3,000 cfs for the following two weeks was established and fish releases were to be made at each export level. However this agreement was not implemented as one of the parties did not initially adjust pumping as proposed. The failure to adjust pumping rates resulted in a combined pumping of approximately 2,250 cfs when marked fish were first released. A resolution was then implemented to maintain pumping at this rate for the full VAMP period. Pumping was approximately 2,250 cfs for the first 26 days of the 31 day VAMP period. Starting on May 26, exports increased gradually because the continued implementation of the reduced export level was increasing the costs (Environmental Water Account debt) to levels unacceptable to the implementing agencies.

Role of Exports with HORB

Exports do not appear to explain additional variability in smolt survival over that using flow alone, in data obtained with the HORB in 1994, 1997 and between 2000 and 2004. This is counter to our conceptual model based on the better relationship of flow/exports and San Joaquin basin escapement 2 ½ years later between 1951 and 2002 than that when using flow alone. In the recovery data from Chipps Island and Antioch (CDRR and DRR) with the HORB installed, regression analyses did show a relationship between the Durham Ferry and Mossdale data and flow/export ratios (Figure 4-14). However, the p value (0.02) indicated lower significance than the regression using flow alone ($p < 0.01$) (Figure 4-8).

The ocean recovery data, while only available for releases prior to 2002, does show a trend of increasing survival with higher flow/export ratios but the relationship is not as statistically significant ($p < 0.10$; Figure 4-15). Again, the relationship using flow alone was stronger (Figure 4-9).

One limitation in these experiments is the extremely narrow range of exports (1,450 to 2,350 cfs) during these smolt survival experiments with the HORB – a narrower range than in the VAMP design and much more narrow than the range of export levels observed since 1951 used in the adult escapement relationships. This narrow range may be why we can not detect a better smolt survival relationship using the flow/export ratio variable than when using flow alone with the HORB in place.

Additional analyses by Dean Marston of California Department of Fish and Game found that the CDRR and DRR's increased as exports increased in simple linear regressions ($r^2 = 0.47$ – Chipps and Antioch recoveries, and $r^2 = 0.69$ – ocean recoveries) of the Mossdale groups relative to the Jersey Point groups, using both Antioch and Chipps Island and ocean recoveries. But when the exports and flow values used in these regressions were regressed against each other, there was a strong relationship between flow and exports ($r^2 = 0.77$) indicating that in general the experiments conducted with the HORB at the lower flows had lower exports and experiments at the higher flows had higher exports (Figure 4-16). It is problematic to identify the respective roles of each variable when the two variables tested are linked in this way.

Our next step is to experiment at flows of 7,000 cfs with the HORB and vary exports (1,500 and 3,000 cfs) to better define the export affect, independent of flow, on smolt survival.

Figure 4-14. The survival between Durham Ferry or Mossdale and Jersey Point (CDRR/DRR) using Antioch and or Chipps Island recoveries and the Vernalis flow/export ratio for the 10 days after the Mossdale release. The data is gathered in years when there was a HORB in place.

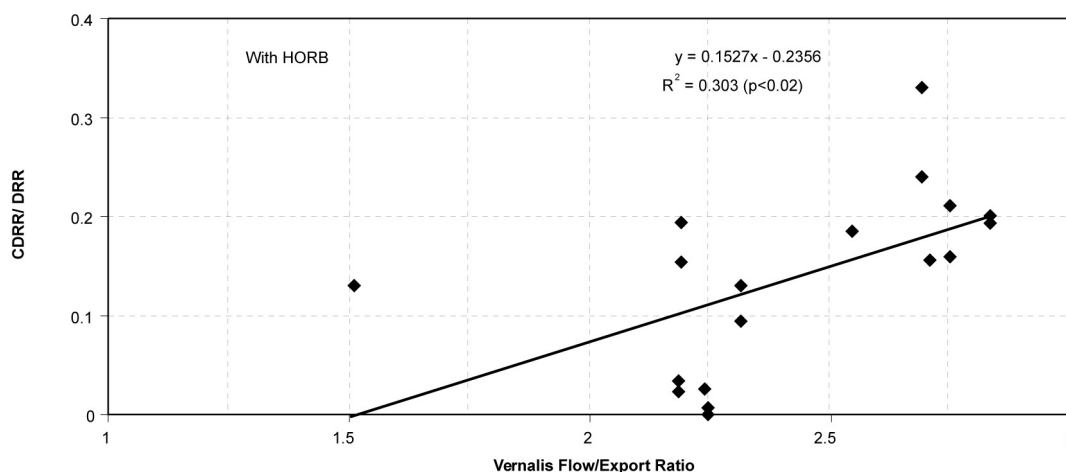


Figure 4-15. Ocean DRR of fish released at Durham Ferry or Mossdale and Jersey Point versus mean Vernalis flow/export ratio 10 days after release with the HORB in place

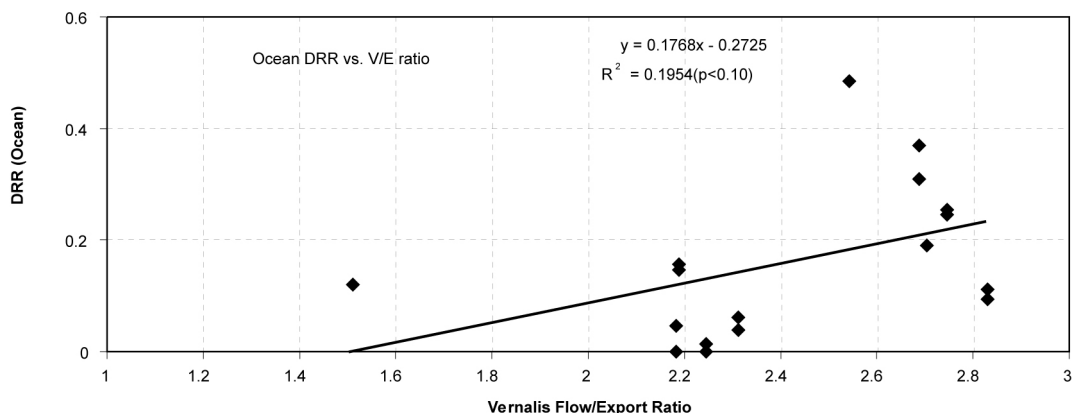
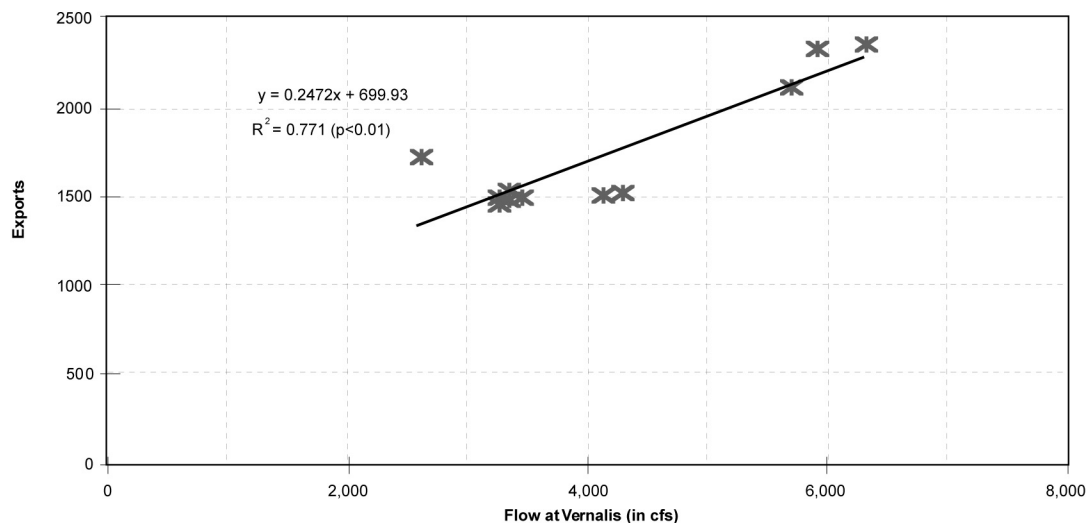


Figure 4-16. The relationship between San Joaquin River flows at Vernalis and CVP+SWP Exports during VAMP smolt survival tests conducted with the HORB in years between 1994 and 2004



Role of Exports without HORB

The role of exports on smolt survival without the HORB in place is even more difficult to identify at this time. As mentioned earlier, relationships of smolt survival without the HORB with flow alone were not statistically significant (Figures 4-10 and 4-11). Regressions of exports to smolt survival without the HORB were weakly or not statistically significant (Figure 4-17) using both the Chipps Island and Antioch and ocean recoveries, but both relationships indicated survival increased as exports increased. The best relationship is a weakly significant multiple regression that includes flow and exports, with survival (using ocean recoveries) increasing as both flow and exports increase ($p < 0.68$, $p < 0.10$). In these data flows and exports were not correlated to each other ($r^2 = 0.0142$), but the export range was limited to between 1400 and 3700 cfs. It is possible that increasing exports in this range decreases residence time in Old river such that survival for those smolts moving into Old River have higher survival. These findings are counter to our hypothesis that survival decreases as exports increase relative to flow.

Regressions between the DRR from Mossdale and Durham Ferry using Chipps Island and Antioch and ocean recoveries did not show a relationship with flow/export ratios (Figure 4-18) – but again these data are limited in the range of export values tested. The adult escapement data which incorporates a larger range in export values indicates a positive and strongly statistically significant relationship ($p < 0.01$) with flow/exports without the HORB but we are not able to detect this same relationship with the smolt survival data we have gathered to date. As in the with HORB data, it will be important to continue these experiments in the future and to measure survival at different export levels at the same flows without the HORB.

Figure 4-17. Chipps Island DRR or Chipps Island and Antioch DRR and ocean DRR for CWT smolts released at Mossdale or Durham Ferry relative to those released at Jersey Point versus combined SWP+CVP mean exports for the 10 days after release in years between 1994 and 2005 when there was no HORB in place..

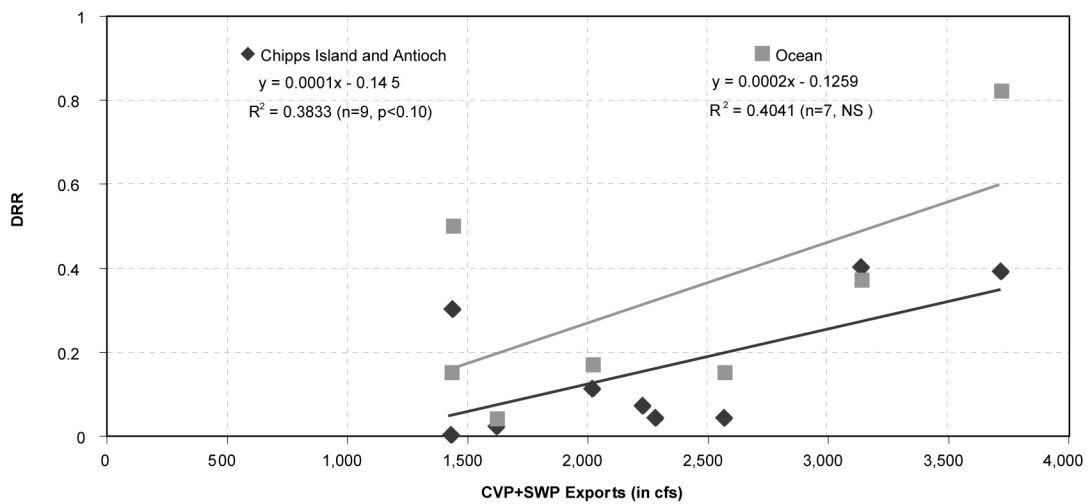
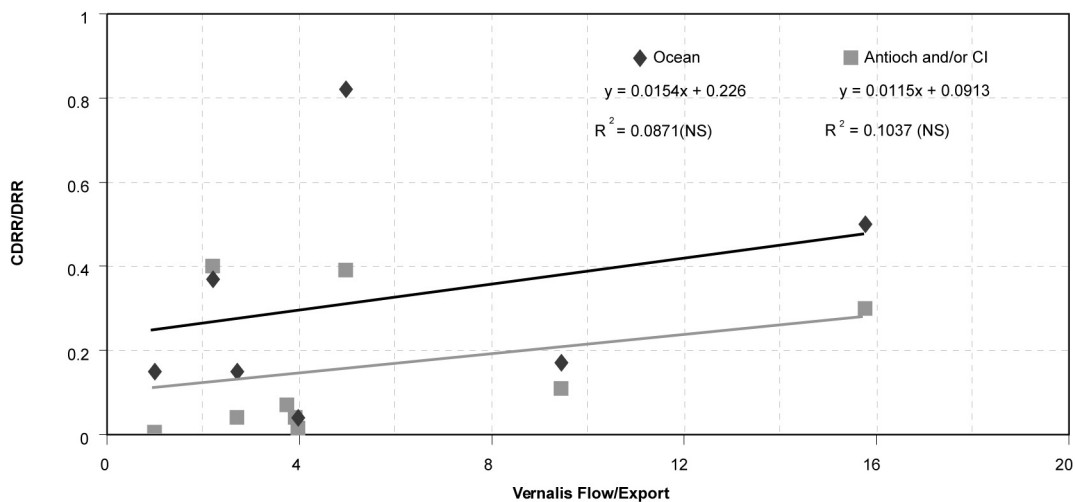


Figure 4-18. Ocean DRR's and Antioch and/or Chipps Island CDRR's or DRR's for fish released at Mossdale and Jersey Point versus the mean Flow/Export ratio for the 10 days after release without the HOR barrier

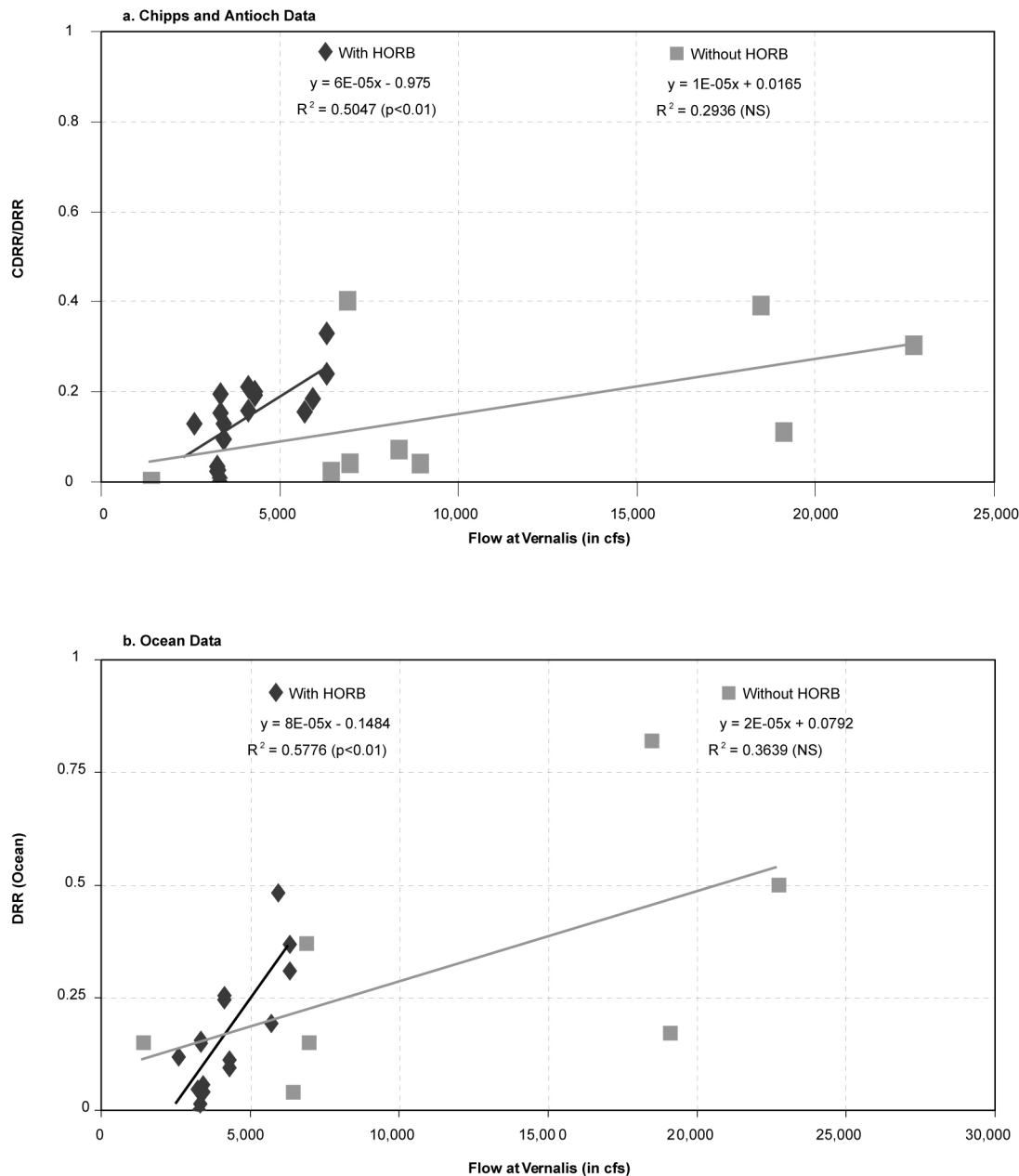


The Role of the HORB on Survival through the Delta

One obvious result of the HORB on survival through the Delta is the lower salvage (and direct loss) for fish released at Durham Ferry and Mossdale when the HORB is installed. In 2005, several hundred of the Durham Ferry group, were salvaged indicating a higher loss compared to previous years because the HORB was not in place.

Comparing the with and without HORB data, using the Chipps Island and Antioch data, appears to indicate that there is value in installing the HORB at flows between about 3,000 and 6,000 cfs (Figure 4-19a). The benefit, using the ocean data, seems less apparent but may improve survival between flows of 4,000 and 6,000 cfs (Figure 4-19b).

Figure 4-19. CDRR or DRR using Chipps Island and Antioch recoveries between Mossdale or Durham Ferry and Jersey Point and average flow at Vernalis in cfs



Relationship of Flow and Exports to Adult Escapement 2 ½ Years Later

The relationships between flow and flow/exports to escapement (all year classes) 2 ½ years later have been shown in previous reports (SJRSA, 2003). In this section of the report, we will present revised escapement data (includes all age classes) which only includes escapement from the Stanislaus, Tuolumne and Merced rivers. Previous estimates included escapement in the Mokelumne, Calaveras and Cosumnes rivers as well. In addition, the data has been updated to include the most recent escapement (to 2004) and flow (to 2002) data. These revised and updated escapement data were obtained from the USFWS Anadromous Fish Restoration Program's website at <http://www.delta.dfg.ca.gov/afrp/index.asp>.

These updated escapement data for the years of 1953 to 2004 was divided into two groups: the first group includes data gathered in those years when the HORB was in place for at least 2 weeks during the smolt out-migration period (April 15 to June 15) 2 ½ years earlier and the second group includes escapement data for those years when there was no HORB. These relationships using both sets of data continue to show that escapement is significantly ($p < 0.01$) correlated to Vernalis flows (Figure 4-20) and Vernalis flows/CVP+SWP exports continues to explain more of the variability in adult escapement than when using flow alone when there was no HORB in place (Figure 4-21). In addition, escapement was significantly correlated to Vernalis flows minus exports (Figure 4-22). The highest r^2 value for the years when there was a HORB in place was for the relationship between adult escapement and flow. This may reflect the relatively low exports in the years the HORB has been in place and the greater effect over a broader range of flow relative to exports on escapement when there wasn't a HORB.

Figure 4-20. Vernalis flows versus escapement 2 ½ years later in years with and without the HORB

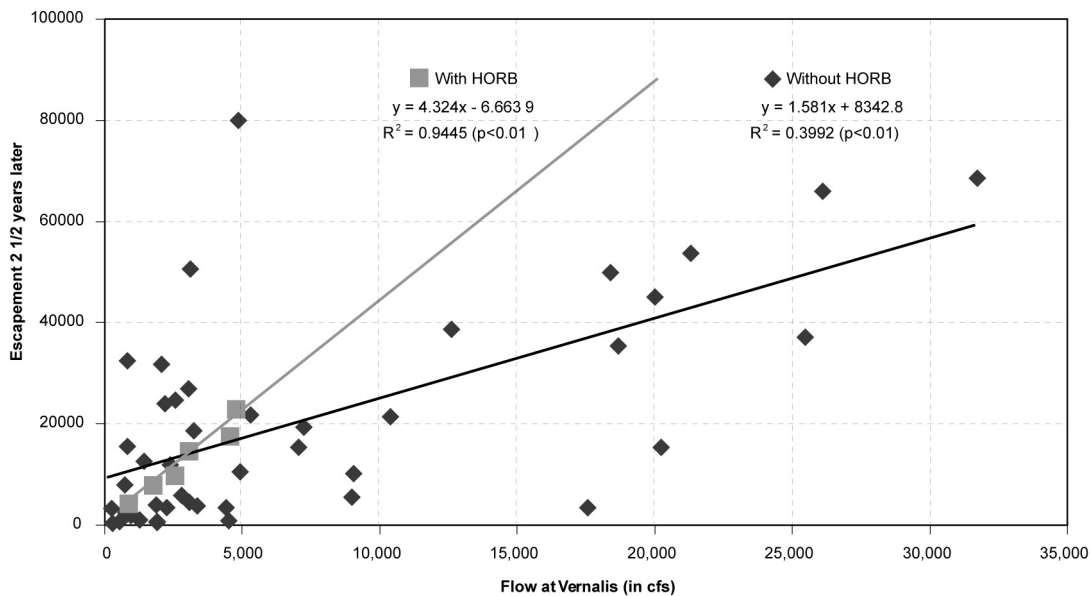


Figure 4-21. Vernalis flow/export ratio versus adult escapement 2 ½ years later in years with and without the HORB in place

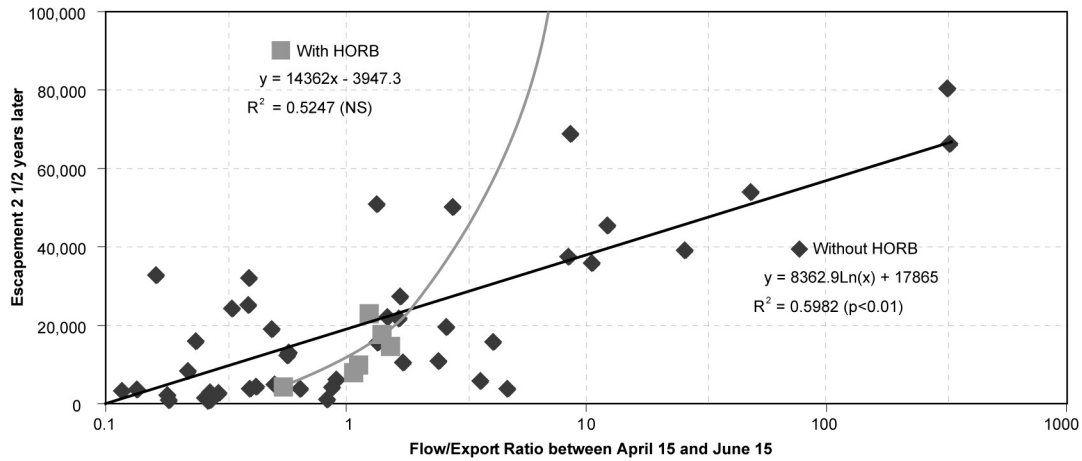
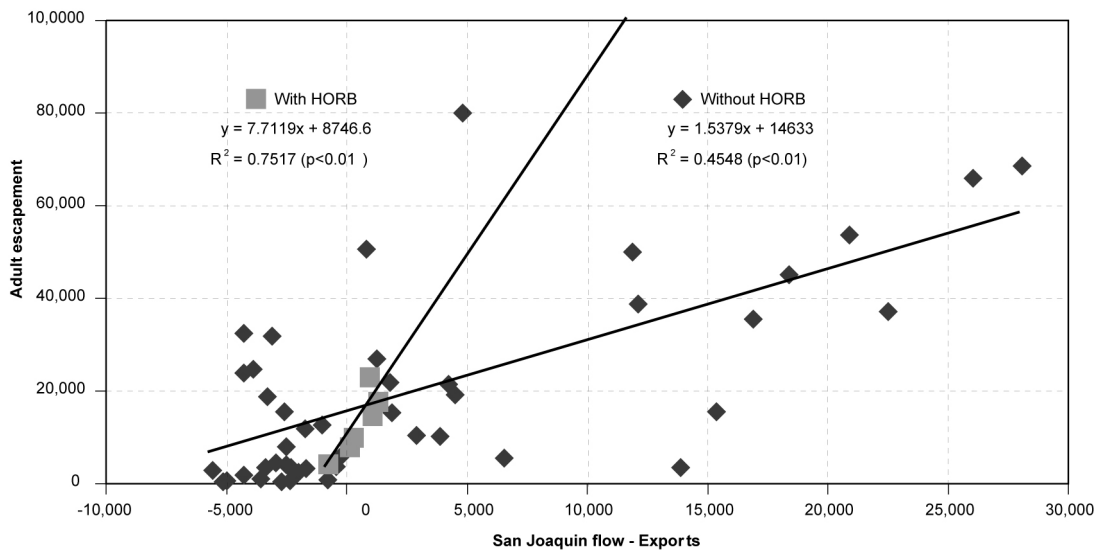


Figure 4-22. Relationship between San Joaquin flow minus exports between April 15 and June 15 and adult escapement 2 ½ years later with and without the HORB in place



In a multiple regression correlating escapement to flows and exports, exports did not provide any additional predictive power to the model than using flow alone. It is not clear why escapement without the HORB is better predicted using the flow/export ratio than flow alone in simple linear regressions, but in a multiple regression, exports do not explain any additional variability in escapement in all years between 1953 and 2004 over that of flow alone. The with and without HORB data was not partitioned in the multiple regression analyses and may explain some of these differences.

In addition, the ratio of exports to flow (opposite of the flow to export ratio) has been used in the past to estimate the amount of flow diverted into HOR when there is no HORB installed (Jim Snow, DWR, personal communication). It is likely the amount of flow diverted affects the proportion of smolts diverted into HOR. The smolts diverted into HOR would likely be more affected by project exports which in turn would affect their overall smolt survival through the Delta and sequential adult returns 2 ½ years later. This relationship between the ratio of

exports/flow and the proportion of flow diverted into Old River may help explain why we see relationships with the flow/export ratio to adult escapement but do not find that exports account for any additional variability in a multiple regression analyses with flow.

The benefit of examining these adult relationships is that there is more data gathered over a broader range than for smolt survival under the VAMP framework. These adult relationships would indicate that as you increase flows and decrease exports relative to flows there should be corresponding increases in smolt survival and adult escapement 2 ½ years later. So while we cannot yet see a significant relationship of flow/exports to smolt survival with the limited data gathered to date, these data would suggest there is a relationship and it predicts adult escapement better than flow alone when there is no HORB. The relationship of flow alone to data gathered with the HORB may reflect the lack of variability in exports with the HORB in place during these experiments as mentioned previously.

When comparing the relationships of escapement and flow with and without the HORB we find that the HORB may have increased escapement between average flows of about 3,000 to 5,000 cfs (Figures 4-20). However, it is not clear that the with and without HORB regression lines are different from one another. Using the relationships of escapement, to evaluate the benefits of the HORB, are imprecise because the HORB wasn't in place for the entire migration period of the juvenile salmon that returned to spawn 2 ½ years later. This is only one of the sources of noise in the escapement data. Additional data are needed to confirm this apparent benefit. Returns based on cohort estimates (specific year classes) would provide an important refinement to this assessment, as the assumption that the majority of spawners are 3-year old fish is known to be inaccurate.

Summary

With the HORB in place we have established statistically significant relationships between smolt survival and flow at Vernalis. These relationships are found using the Chipps Island and Antioch smolt recovery data and the ocean recovery data. The smolt survival data obtained without the HORB show a trend of increasing survival as flows increase but relationships are weaker and not statistically significant. The relationship between ocean recovery rates of the Dos Reis groups relative to the Jersey Point groups indicate that survival improves as flows increase for smolts that remain within the mainstem San Joaquin River when there is no HORB. The role of exports on smolt survival within the VAMP (with HORB) and without a HORB is more difficult to define based on the limited data. It is imperative that we measure the two export rate conditions (1,500 and 3,000 cfs) at flows of 7,000 cfs with a HORB in place so that the uncertainty can be resolved. Additional data should also be gathered without the HORB. Finally, the relationships with adult escapement infer that survival through the Delta can be improved with 1) increased flow when there is a HORB, 2) increased flow/export ratios when HORB is not installed, and 3) with a HORB at flows between 3,000 and 5,000 cfs.

San Joaquin River Salmon Protection

One of the VAMP objectives is to provide improved conditions to increase the survival of juvenile Chinook salmon smolts produced in the San Joaquin River tributaries during their downstream migration through the lower river and Delta. It is hypothesized that these actions to improve conditions for the juveniles will translate into greater adult abundance and escapement in future years.

To determine if VAMP has been successful in targeting the migration period of naturally produced juvenile salmon smolts, catches of unmarked salmon at Mossdale and in salvage at the CVP and SWP facilities were compared prior to and during the VAMP period.

Unmarked Salmon Recovered at Mossdale

The typical time period for VAMP (April 15 to May 15) was chosen based on historical data that indicated a high percentage of the juvenile salmon smolts emigrating from the San Joaquin tributaries passed into the Delta at Mossdale during that time. In 2005, the VAMP period was delayed until May 1 with the intent of providing more stability in the river flows at Vernalis. The average catch per 10,000 cubic meters per day of unmarked juvenile salmon caught in Kodiak trawling at Mossdale between March 15 and June 30, 2005. Unmarked salmon do not have an adipose clip and could be juveniles from natural spawning or unmarked fish released from the MRFF.

Approximately 65% of the unmarked catch that passed Mossdale between March 15 and June 30 passed during this years VAMP period (May 1 – June 1) (Figure 4-23). The range has varied between 31 and 76% in the pervious VAMP years since 2000 (SJRG, 2005). The pre-VAMP shoulder on VAMP that restricted exports between April 18 and May 1 provided protection to an additional 14% of the population in 2005 (Figure 4- 23). The size of the juvenile salmon migrating past Mossdale between March 15 and June 30, 2005 is shown in Figure 4-24.

Figure 4-23. The average daily densities of unmarked salmon caught in the Mossdale Kodiak trawl on the San Joaquin River and the percent of smolts protected during the pre-VAMP and VAMP periods

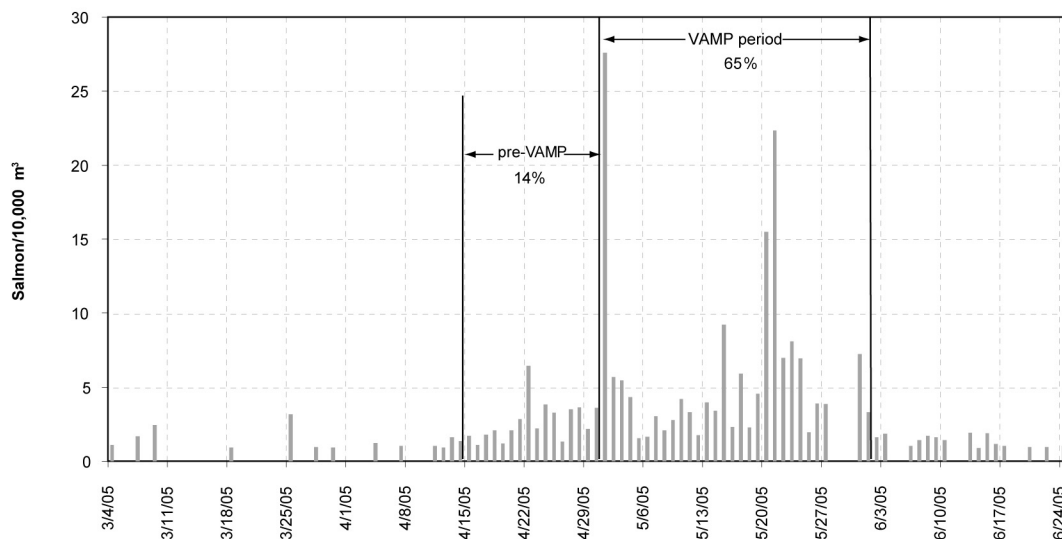


Figure 4-24. Mossdale Kodiak trawl individual daily forklengths of all unmarked juvenile Chinook salmon, March 15 through June 30, 2005



Salmon Salvage and Losses at Delta Export Pumps

Fish salvage operations at the CVP and SWP export facilities capture unmarked salmon and transport them by tanker truck for release in the western Sacramento-San Joaquin Delta. The untagged salmon are potentially from any source in the Central Valley. It is not certain which unmarked salmon recovered are of San Joaquin basin origin although the timing of salvage and fish size can be compared with Mossdale trawl data and CWT recovery data for MRFF smolts at the salvage facilities to provide some general indications as to the origin of the unmarked fish.

The losses at the CVP and SWP are based on expanded salvage and an estimate of screen efficiency and survival through the facility and salvage process. The CVP pumps divert directly from the Old River channel and direct losses are estimated to range from about 50 to 80% of the number salvaged. Four to five salmon are estimated to be lost per salvaged salmon at the SWP because of high predation rates in Clifton Court Forebay. The CVP losses are about six to eight times less, per salvaged salmon, than for the SWP. The loss estimates do not include any indirect mortality in the Delta due to water export operations, or any additional mortality associated with trucking and handling, or post-release predation.

Density of salmon at the fish facilities is represented by the combined number of salvage and losses estimated per acre-foot of water pumped. This approach provides more comparable densities at each facility than density values based only on salvage estimates that were used previously, due to the different calculation of associated losses at each location. The DFG and DWR maintain a database of daily, weekly, and monthly salvage data.

The number and density of juvenile salmon that migrated through the system, the placement of the HORB, and the amount of water pumped by each facility are some of the factors that

influence the number of juvenile salmon salvaged and lost. Density is an indicator of when concentrations of juvenile salmon may be more susceptible to the export facilities and salvage system.

The weekly data covering the period of May 1 to May 28 approximated the 2005 VAMP period. A review of weekly data for January through June indicates that the highest CVP salvage and loss occurred from late April to early May. Lesser peaks occurred between late March and early April and in early February (Figure 4-25). Highest SWP salvage and loss were in late April with a sustained broad peak from mid-May to mid-June (Figure 4-26). The primary CVP and SWP peaks occurred during an extended period of late March to mid-June when combined CVP and SWP weekly export rates were equal to, or exceeded by Vernalis flow (Figure 4-27).

Salmon densities at the CVP facilities were highest in late April to early May, with an earlier peak in late March (Figure 4-28). Densities at the SWP facilities were highest in the second half of May and were elevated from mid-April through early June (Figure 4-28).

The size distribution of unmarked salmon during mid-March through May in the Mossdale trawl (Figure 4-24) was a subset of the size distribution of those salvaged at the fish facilities (Figure 4-29, Source E. Chappell, DWR). Based on comparisons with Mossdale data, it appears that some salmon salvaged prior to VAMP could have been from the San Joaquin basin.

Results of these analyses showed that the 2005 VAMP test period and the pre-VAMP curtailment in exports for Delta smelt coincided with much of the peak period of San Joaquin River salmon smolt emigration. Reductions in SWP and CVP exports and increased San Joaquin River flow likely provided improved conditions for salmon survival through the Delta.

Figure 4-25. 2005 CVP estimated salmon salvage and loss

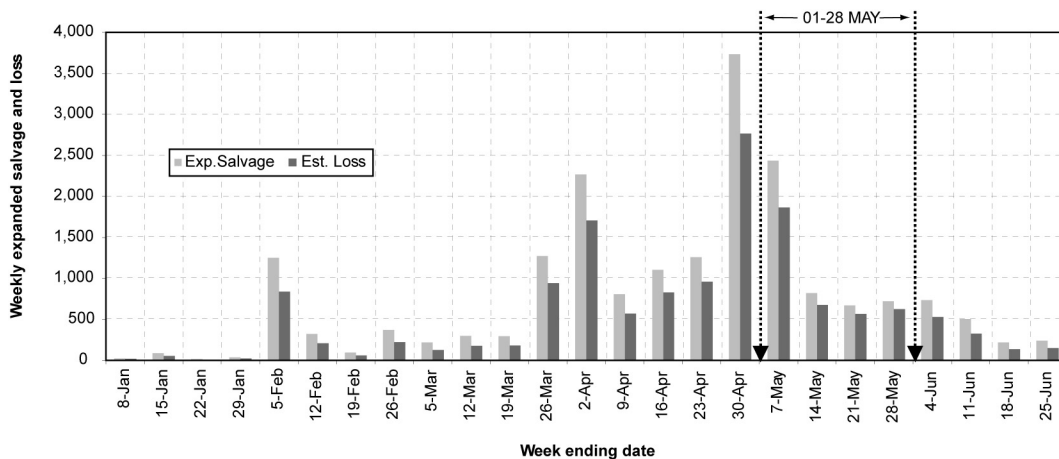


Figure 4-26. 2005 SWP estimated salmon salvage and loss

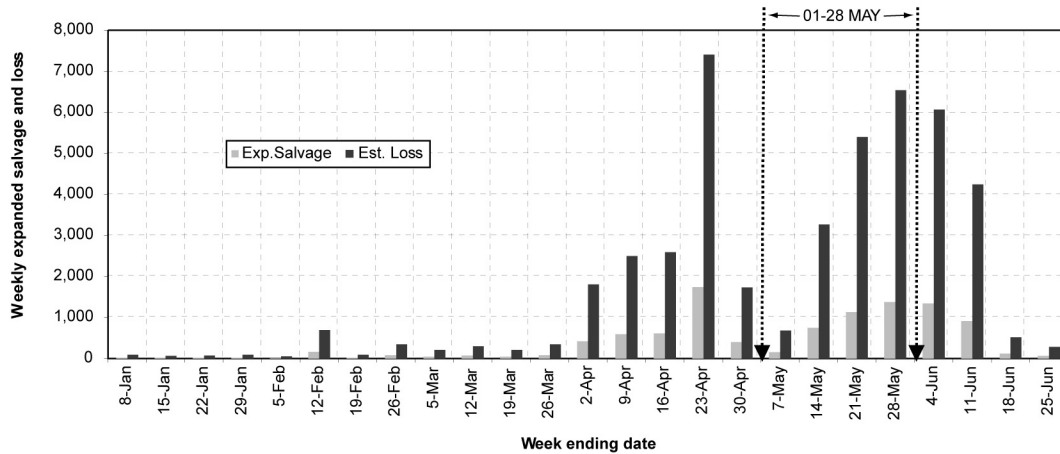


Figure 4-27. 2005 Weekly export rates and Vernalis flow

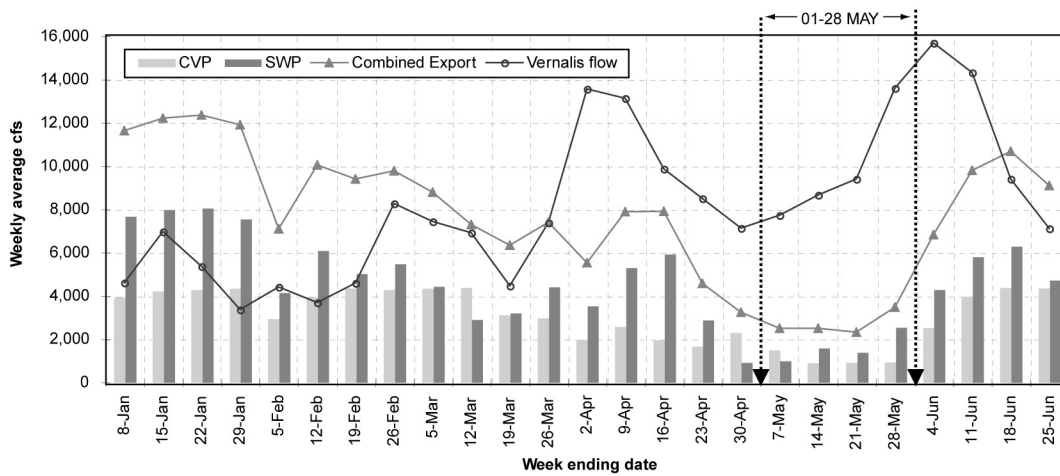
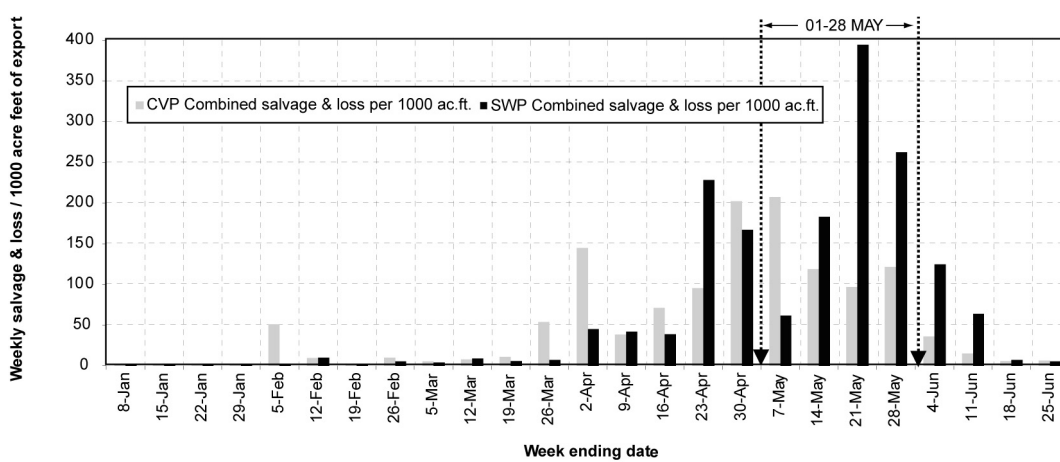
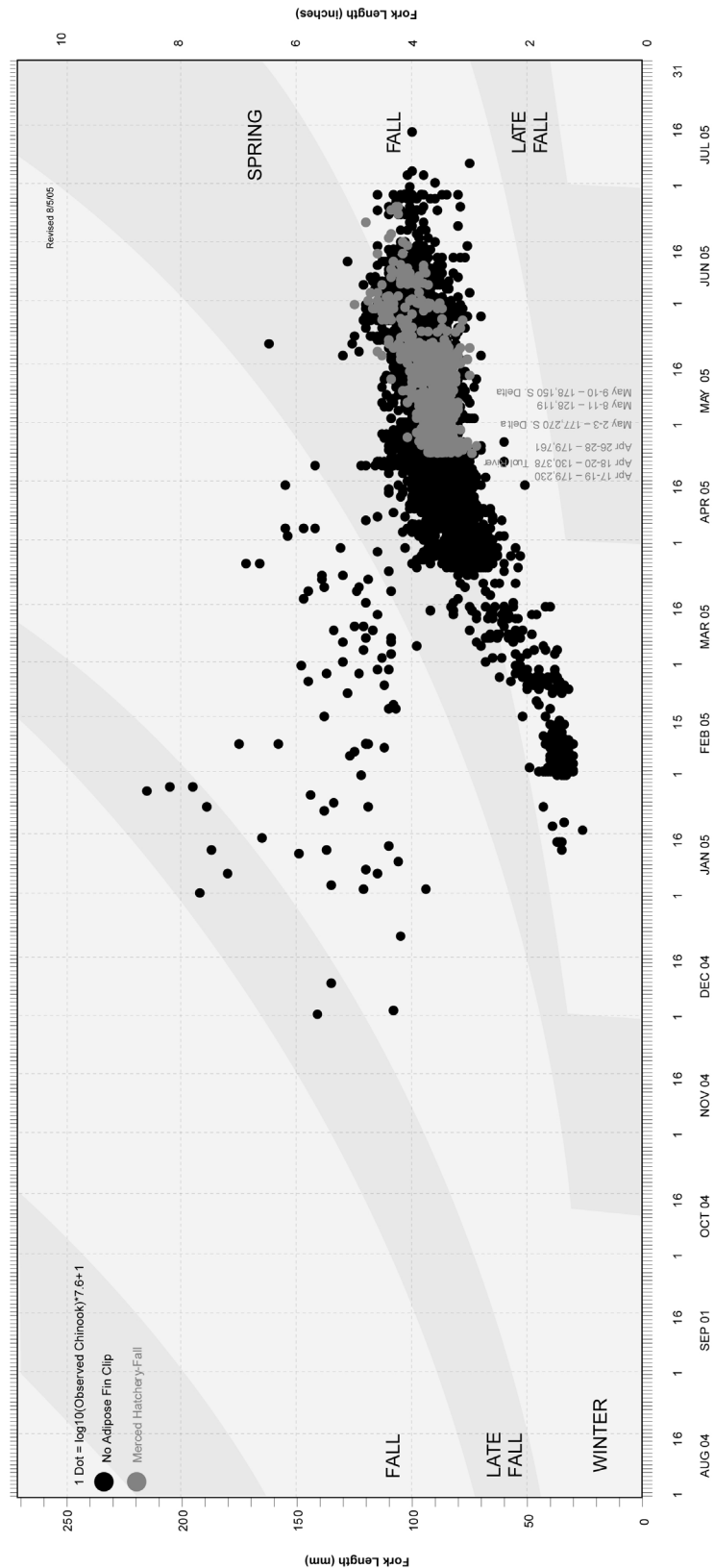


Figure 4-28. 2005 CVP and SWP combined salvage and loss density



**Figure 4-29. Observed Chinook salvage at SWP and CVP Delta fish facilities
8/1/04 Through 7/31/05**



Summary and Recommendations

The survival estimates and CDRRs measured in 2005 were low and similar to those estimated in 2003 and 2004. One of the reasons 2005 survival was low was due to the fact that there was no HORB installed. We would have predicted higher survival if the HORB had been installed.

The health of the fish used in 2005 was again somewhat suspect and improving their condition should be discussed with those responsible for fish production in the basin. Specifically, factors that could reduce the incidence of the parasite that causes PKD should be identified. The CA/NV FHC has shown PKD is also in the wild population in the San Joaquin basin. The survival indices were consistently low for all of the marked fish released from MRFF, with the exception of those released at Jersey Point. However, the survival of fish released at Jersey Point may have been reduced after they passed Chipps Island because they also had PKD but in general were recovered sooner than those released upstream.

There are statistically significant relationships of smolt survival and flow with the HORB. These relationships are found using the Chipps Island and Antioch recoveries of the Durham Ferry and Mossdale groups relative to the Jersey Point groups and when using ocean recoveries. Escapement 2 ½ years later was also significantly ($p < 0.01$) correlated to San Joaquin River flow at Vernalis with a HORB.

There is also a trend of increasing smolt survival with San Joaquin River flow without the HORB but the relationships are not statistically significant. There is however, a statistically significant relationship between spring flows without a HORB and adult escapement 2 ½ years later. Without a HORB the best predictor of escapement is the flow/export ratio.

To better determine relationships of smolt survival to exports and flow, certain conditions should be targeted during the remaining years of VAMP and in years when the HORB cannot be installed. Two of the conditions that need to be tested are at exports at 1,500 and 3,000 cfs with San Joaquin River flows at 7,000 cfs with the HORB in place. In addition, the 7,000 cfs flow and the 1,500 export condition would achieve the highest inflow to export ratio (4.7) within the VAMP design and provide a larger ratio to test. Unless these extremes are tested soon, the length of the study may need to be extended. Furthermore, more data should be obtained when the HORB cannot be installed to further refine and define the survival relationships to flow and exports without the HORB in place.

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Chapter 5. Barrier Effects on SWP and CVP Entrainment

Introduction

Using methods incorporated by Ted Sommer et al (2005) in examining the role of hydrology in the Delta Pelagic Organism Decline (POD), a coupled hydrodynamic-particle tracking model (PTM) was used to assess the effect of Temporary Barriers Project (TBP) south Delta agricultural barriers' (ag. barriers: Old River near Tracy barrier (ORB), Middle River barrier (MRB) and Grant Line Canal barrier (GLCB)) installation and operation on the risk of entrainment by Delta fishes that occur near the confluence of Old River and Middle River (Figure 5-1). Despite limitations of this modeling tool (i.e. a lack of behavior, mortality, vertical movement, growth, etc. on particles), simulations of particles injected into the Delta infer direct entrainment risk. The percentage of particles entrained into the Clifton Court Forebay (CCF) and the Tracy fish collection facility is assumed to represent the likelihood of fish entrainment at the State Water Project (SWP) and Central Valley Project (CVP) south Delta export facilities. Earlier treatments have suggested that the application of this method to multiple injection sites (Figure 5-1) in the central and south Delta may account for an unknown or variable distribution of fishes subject to entrainment. This report concentrates on the single injection site, and reports data without further statistical analyses.

Methods

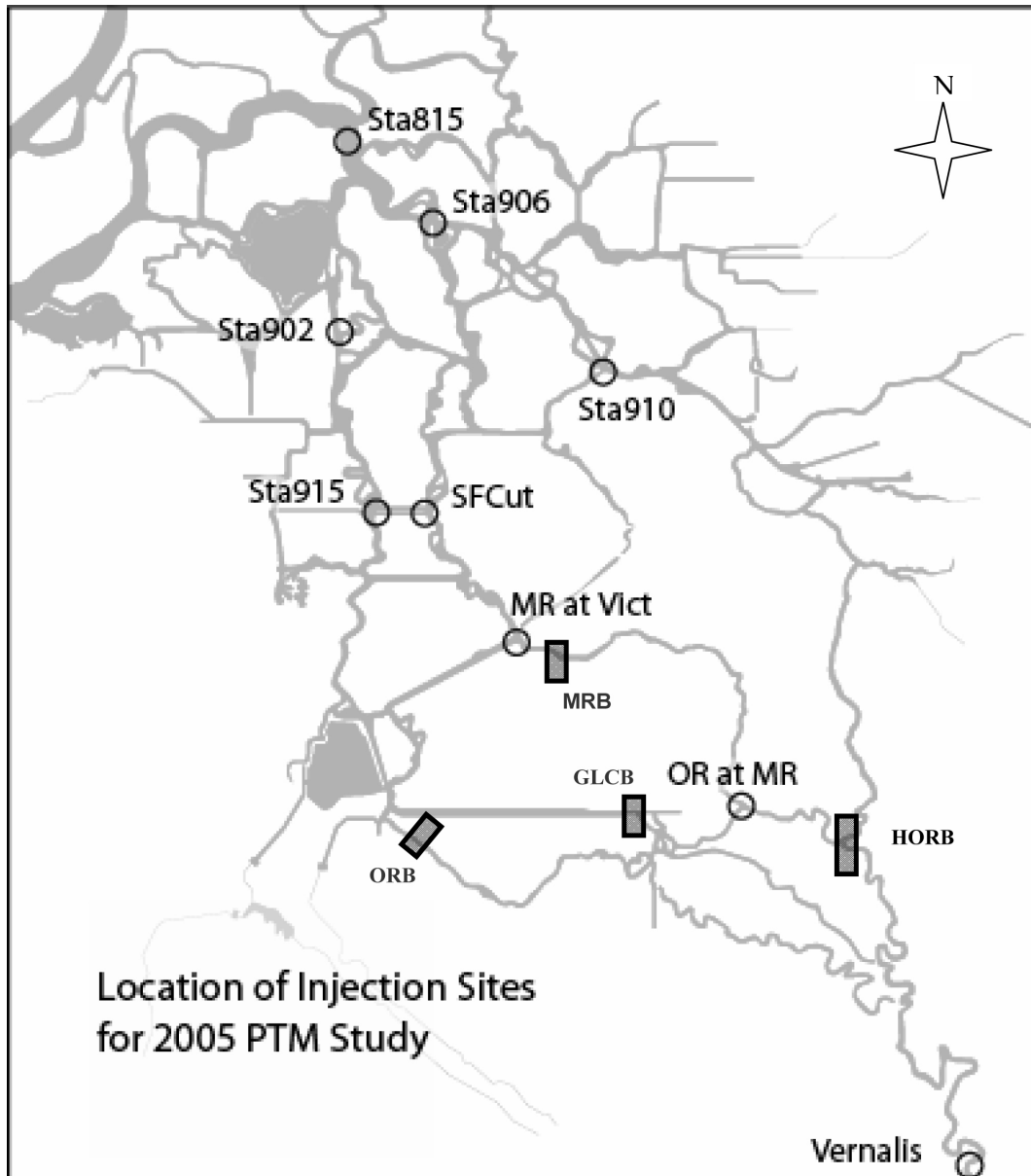
Modeling

DWR modeled daily injections using historic conditions, including the actual installation of the TBP barriers, for the 2005 calendar year (historical simulation) (Suits, 12/15/06 and 7/6/06). Since 90 post-release modeling days were required to determine particle fate, simulations were conducted for the period of January 1 through October 2, 2005. A modified simulation was then run assuming no installation and operation of the three agricultural barriers, in order to examine the effect of the barriers on entrainment through comparison with the historical simulation. A similar approach was recently used in generating information for the Department's testimony in the Bay-Delta Hearings on the SWRCB Cease and Desist Order, for which modelers varied SWP pumping from historic levels (Bob Suits, pers. comm. 12/28/05). Both models included the installation and operation of the Fall Head of Old River Barrier (HORB) as it occurred in 2005.

The PTM continuously simulated transport and fate of particles throughout the modeling period. Particle fate was broken down into the following components: 1) downstream of Chipps Island; 2) diverted onto Delta islands; 3) exported from the SWP (south Delta); 4) exported by the CVP; 5) exported by Contra Costa Canal; and 6) remaining in Delta channels. When these values are added, they sum to 100 percent for any moment in time. Running for 90 days after injection typically gave the particles sufficient time to have fate determined (Bob Suits, pers. comm. 4/17/06) (Bob Suits Memo, 2006). For purposes of this evaluation of entrainment risk, only south Delta SWP and CVP fate data were used.

CCF inflow and project export pumping data were provided by DWR (Amritpal Sandhu, 2006) and were reviewed for obvious potential influence on particle entrainment.

Figure 5-1. Map of south and central Delta, including the locations of the South Delta Temporary Barriers (Old River Barrier, Grant Line Canal Barrier, Middle River Barrier, Head of Old River Barrier) and particle injection sites used in the 2005 PTM study.



Analysis

The total percentage of daily-injected particles entrained by the SWP and CVP after 90 days were used to represent a potential or indicator of flow conditions conducive to fish entrainment. Variation in this measure of particle entrainment is due to changing hydrology including Delta inflow, CVP pumping, CCF inflow and numerous small diversions, and to changing geometry such as the installation, removal and operational changes of one or more of the temporary barriers. We anticipated that simulated entrainment differences at the CVP and SWP facilities would eventually help to infer specifically, which changes in operation of the agricultural temporary barriers contributed to changes in total fish entrainment at the project facilities.

The time series was broken down into a dozen overlapping periods defined by major hydrologic and geometric configurations in the south and central Delta. For each block of time, the percent daily entrainment for the historical simulation were subtracted from those resulting from the modified simulation. The period average difference in daily entrainment percentage was used as a measure of barrier-induced entrainment risk. These data are listed in Table 5-1 for specific periods. A positive (+) value indicated that average daily entrainment for the modified simulation exceeded average daily entrainment for the historical simulation. Therefore, simulated entrainment was less with the barriers in place than without. A negative (-) result, therefore, indicated the opposite.

A non-statistical measure of significance was applied to these results, using a test for background noise. Since simulated hydrology was expected to be equal for both runs during the period prior to barrier installation, 1/1 –5/11/06, the greatest daily difference observed represents the maximum amplitude of background noise resulting from the modeling process. This artificial error threshold was determined for SWP, CVP and combined projects (Table 5-1). Period average daily percent differences were determined to be great enough to warrant further attention, when their values superseded the daily maxima (max diff) in background noise.

Table 5-1. Difference in percentage of particles injected daily into Old River at Middle River and subsequently entrained by the State Water Project and/or Central Valley Project for each modeling condition (modified simulation - historical simulation), for the examined periods in 2005.

Evaluation Period		Project Average Daily Percent Difference in Entrainment (Simulated)		
DESCRIPTION	DATE	SWP	CVP	SWP + CVP
Noise Evaluation Period (max diff)	1/1-4/14	0.0 (+/- 1.7)	-0.0* (+/- 1.0)	0.0 (+/- 0.3)
Full Modeling Period	1/1-10/2	-0.1	2.3	2.1
MRB, ORB & HORB Only Period	4/15-7/13	1.6	-1.6	0.0
Spring HORB Period	4/15-5/24	-0.2	0.3	0.1
VAMP Period	4/15-5/15	-0.1	0.2	0.1
Spring HORB Only Period	4/15-5/11	0.0	0.2	0.2
Ag. Barriers Period	5/12-10/2	-0.3	4.3	4.0
MRB & HORB Only Period	5/12-5/23	-0.7	0.6	-0.2
Ag. Barriers Only Period	5/25-10/2	-0.3	4.7	4.4
ORB Install Onward Period	5/31-10/2	-0.2	4.9	4.7
ORB before GLCB Period	5/31-7/13	2.7	-2.6	0.1
GLCB Install Onward Period	7/14-10/2	-1.8	8.9	7.1

- negative sign indicates that the value was negative prior to rounding.

Results

The combined (SWP and CVP) period average daily percent difference in particle entrainment at the Tracy fish collection facility and at CCF represents the potential influence of the 2005 TBP operations on fish entrainment risk. Assuming that simulated particle entrainment is proportional to fish entrainment risk, modeling results show that particle entrainment, and therefore potential fish entrainment risk without the agricultural barriers was greater by approximately 2.1 percent for the entire modeling period (Full Period, 1/1 – 10/2/05). The simulated period of operation for the three agricultural barriers, (Ag Barriers Period, 5/12 – 10/2/05), had a period average difference in percent daily particle entrainment of plus four percent when the barriers were not in place. The influence of the Fall HORB was removed from this calculation by excluding entrainment for days following its installation on 9/28/05. The resulting period average daily percent difference in entrainment did not change significantly (Ag Barriers Before HORB Period, 3.9%, 5/12-9/27/05). Evaluation of the ORB and MRB showed that they had almost no effect on combined particle entrainment (MRB Only Period, -0.2%, 5/12-5/30/05; MRB Before GLCB Period, -0.0%, 5/12-7/13/05; ORB Before GLCB Period, 0.1%, 5/31-7/13/05). The greatest changes in average daily percent entrainment between simulated conditions occurred following installation of the GLCB on 7/14/05 (GLCB Install Onward Period, 7.1%, 7/14-10/2/05; GLCB Before HORB Period, 7.2%, 7/14-9/27/05) and the Fall HORB on 9/28/05 (Fall HORB Period, 8.5%, 9/28-10/2/05). During these periods, the simulation of historic conditions resulted in significantly less entrainment of particles than occurred with the barriers-excluded modified simulation. The remaining evaluated periods including the aforementioned ORB before GLCB Period (0.1%, 5/31-7/13/05), and the Vernalis Adaptive Management Plan period (VAMP) (0.1%; 4/15-5/15/05) each exhibited a less than significant period average difference in daily percent entrainment. The pre-barrier installation period (Noise Examination Period, 0.0%, 1/1-5/11/05) resulted in zero period average daily percent difference for the SWP, CVP and combined projects. Maximum differences for the three project groups were as follows: SWP, 2.1%; CVP, -1.7%, SWP + CVP, 2.9%.

Discussion

The PTM simulation results indicated that the installation and operation of the three agricultural temporary barriers was conducive to lower particle entrainment at the SWP and CVP south Delta facilities for 2005 conditions. Differences in entrainment between the two simulations were greatest toward the end of the modeling period. Installation of the GLCB and HORB coincided with the greatest distinction in particle entrainment between the two model runs. Unfortunately, due to their overlapping operation this approach did not allow for independent examination of the two barriers for entrainment risk.

Since many variables are involved in the entrainment of fishes in the south Delta, conclusions drawn from the relationship between historic conditions and particle entrainment were not extended with much certainty to fish entrainment. The results do, however, examine whether the combined effects of barrier operation timing, associated hydrology, and concurring changes in particle entrainment seem likely to correlate with entrainment of fishes that tend to go with the flow of water, and most likely to similarly affect fishes with lower swimming performance. The latter group includes larval and juvenile fishes, as well as poor-swimming species like delta smelt, which utilize diel shifts in vertical position in response to tidal flows for mobility (Moyle, 2002). The relationship between these variables is less straight-forward than it may seem, and should be examined further by fisheries biologists.

With all three ag. barriers in place, most particles injected into Old River at Middle River were entrained by the CVP (Figure 5-2). This occurred despite the fact that the CCF exported more water from the south Delta than the TPP (Figure 5-3), suggesting that exports alone are not strongly tied to fish entrainment risk, and that the operation of the south Delta temporary ag. barriers likely limited fish entrainment risk in 2005.

Figure 5-2. Average percent of daily-injected particles subsequently entrained by the SWP and CVP as simulated under historic conditions for the examined periods in 2005

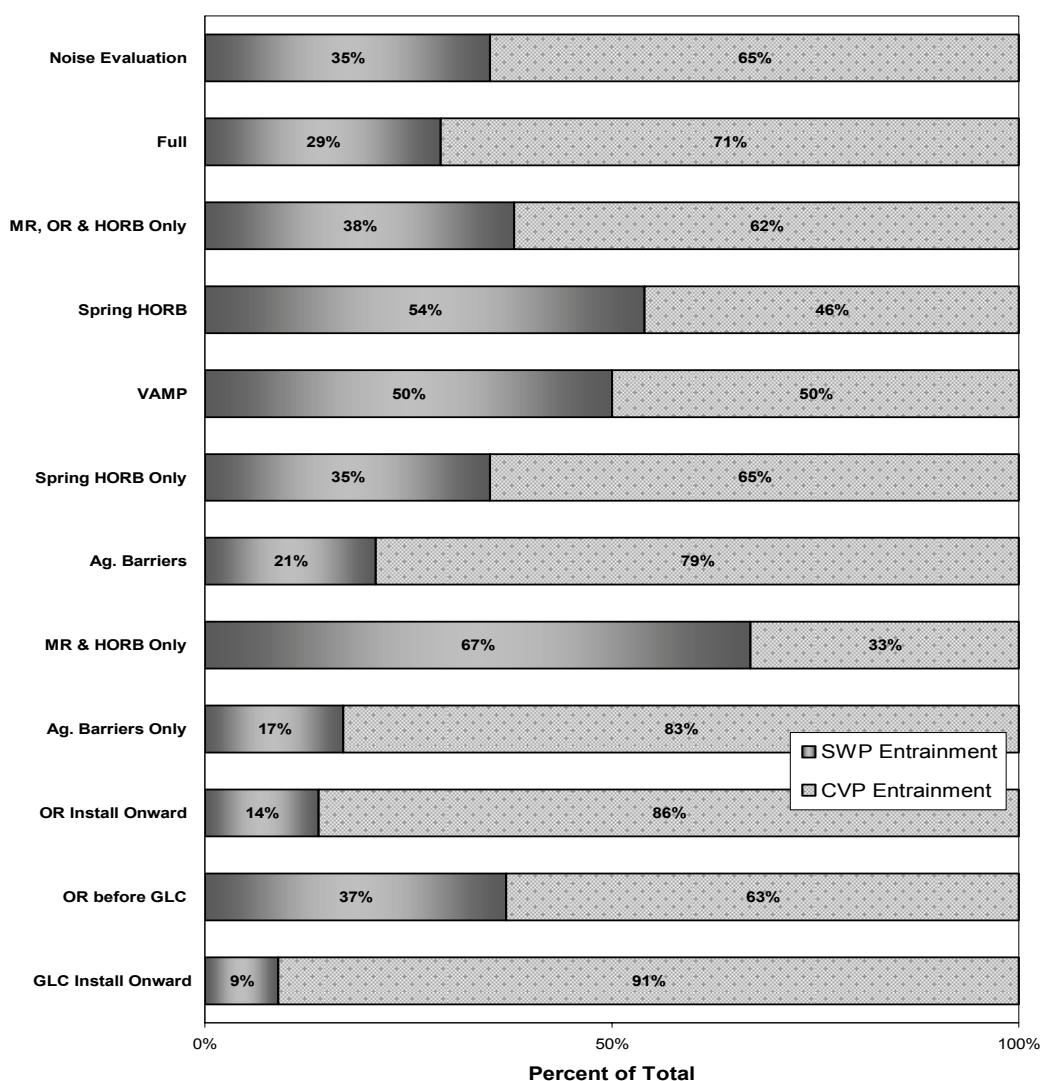
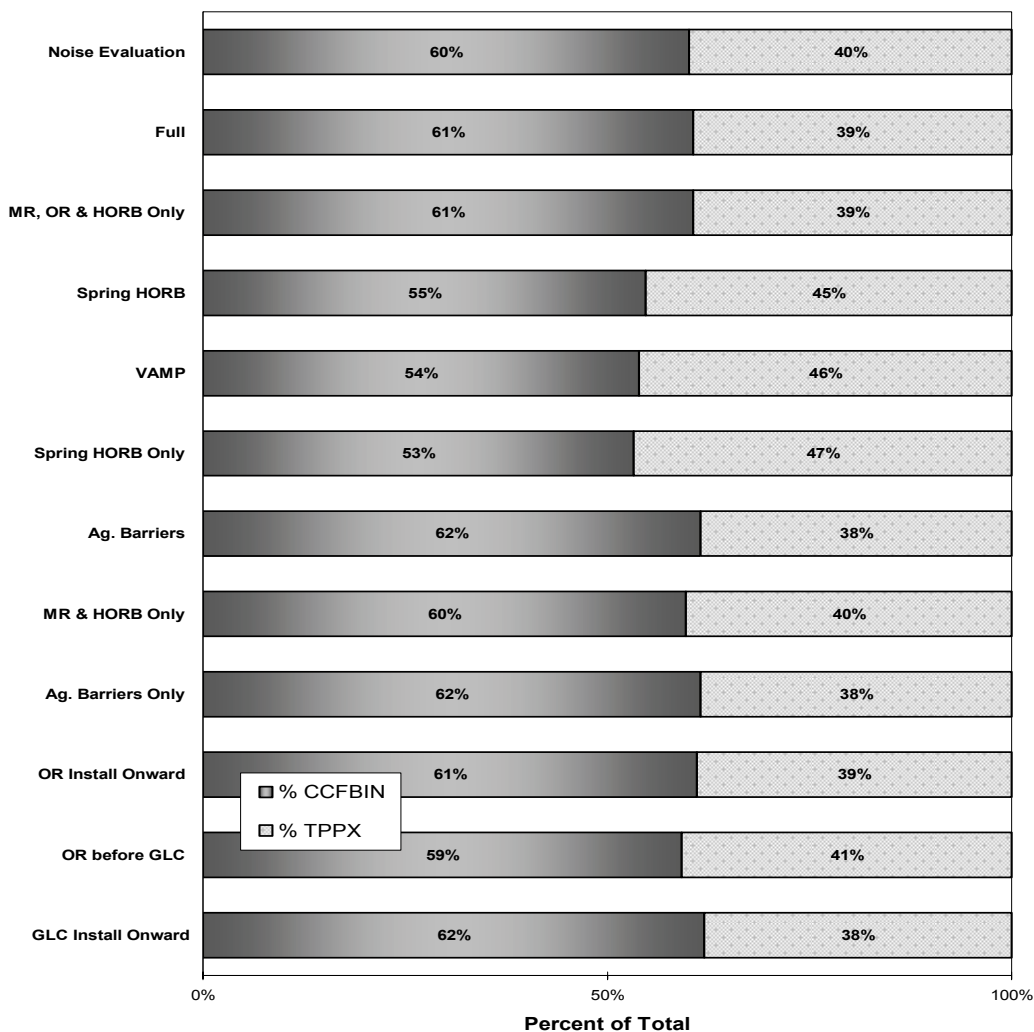


Figure 5-3. Average daily percent of CCF inflow (SWP) and Tracy Pumping Plant exports (CVP) relative to total water diverted by the south Delta projects (CCFBIN + TPPX) for the examined periods in 2005



Future PTM Ideas

Although the PTM design and evaluation used here helps illustrate the entrainment of neutrally buoyant particles in a simulated environment, it lacks a method to relate such results to fishes in the real world. Other modelers have applied artificial behavior to particles by removing a degree of randomness from simulations. For delta smelt, an example might include forcing vertical diel shifts through a water column with variable flow rates at depth. A fisheries biologist could apply entrainment risk data calculated here to real-world populations occurring in the south and central Delta.

Barring a more intensive effort, this evaluation may be applied for multiple injection sites throughout the Delta, such as those depicted in Figure 5-1. Further evaluation should include the unused particle fate components listed in the Modeling section of this report. This method could be applied to the historic record, to evaluate particle entrainment over different water year types. An effort should be made to seek out an appropriate statistical analysis to apply to the data, which could determine whether causal relationships exist between the observed variables.

Resources

- Moyle, Peter. 2002. Inland Fisheries of California. Berkeley and Los Angeles, California. University of California Press.
- Sandhu, Amritpal 2006. Water Resources Engineer, Operations Compliance and Studies Section, SWP Operations Control Office, DWR. Provided CCF inflow and export pumping data.
- Sommer et. al., 2005. Sommer, Ted, Bob Suits, Michael Mierzwa and Jim Wilde. Draft, September 30, 2005. Evaluation of Residence Time and Entrainment using a Particle Tracking Model for the Sacramento-San Joaquin Delta. California Department of Water Resources. Sacramento, California. 32 pp.
- Suits, Bob 7/6/06. Memo from Bob Suits, Senior Engineer Delta Modeling Section, to Tara Smith, Chief of Delta Modeling Section, Bay-Delta Office, CA Department of Water Resources. Subject: Use of Particle Tracking Modeling to Generate Index of Entrainment Potential.
- Suits, Bob 12/28/05. Email from Bob Suits, Senior Engineer Bay-Delta Office, CA Department of Water Resources.
- Suits, Bob 2/15/06. Email from Bob Suits, Senior Engineer Delta Modeling Section, Bay-Delta Office, CA Department of Water Resources. Designed and implemented PTM simulations, and provided output data used in this chapter.
- Suits, Bob 4/7/06. Email from Bob Suits, Senior Engineer Delta Modeling Section, Bay-Delta Office, CA Department of Water Resources.

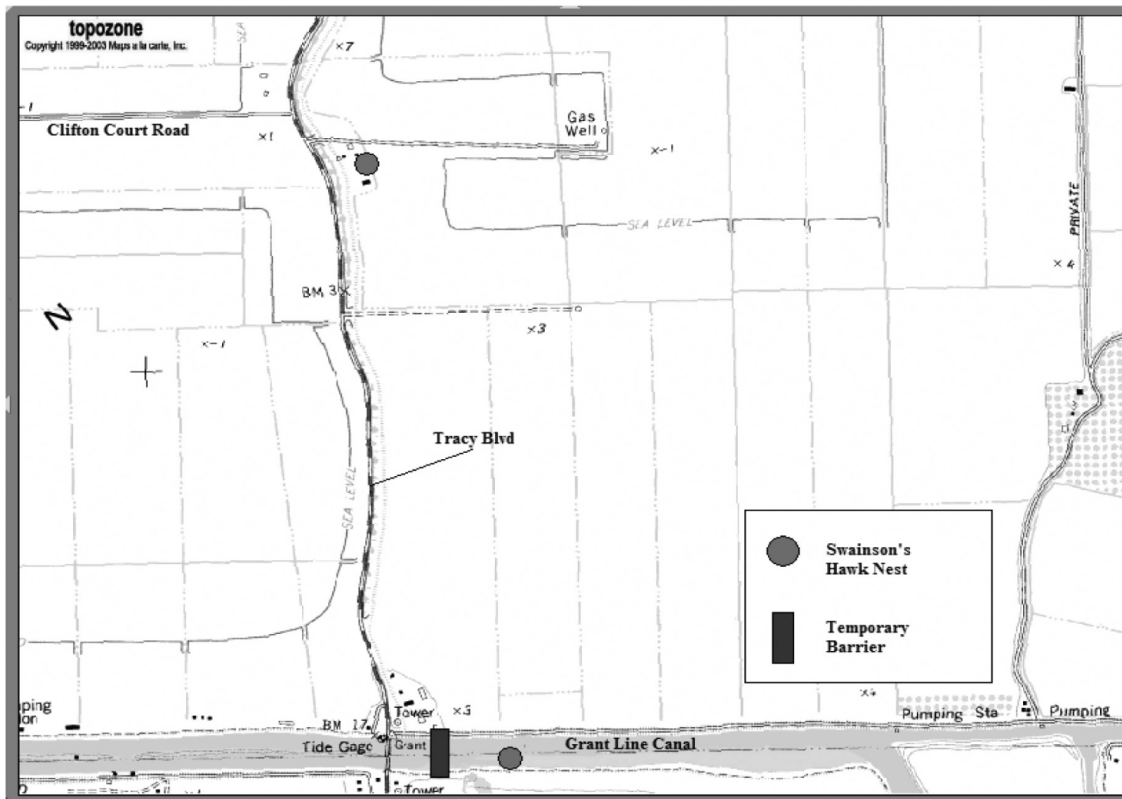
Chapter 6. Swainson's Hawk Monitoring

Swainson's hawk surveys were initiated around the Temporary Barriers construction and staging sites on 24 March for the 2005 construction period, and monitoring continued through June 14. Five pairs of Swainson's hawks nested adjacent to or near the construction sites associated with the three agricultural barriers.

Grant Line Canal

Two pairs of Swainson's hawks nested near the construction site and haul road (Figure 6-1). One pair nested in a large oak tree 300 yards east and upstream of the barrier site on Grant Line Canal. Eggs were laid later than average, beginning around April 28. The first of two chicks hatched about May 31. Both chicks were visible through June 14, but in the last week of June, both were gone from the nest, although both adults were perched nearby. The chicks may have died from West Nile Virus, been blown out of the nest by strong Delta winds, or they may have been killed by a predator such as a great horned owl. Barrier construction had been completed and it is unlikely that construction activities had anything to do with the failed nest.

Figure 6-1. Swainson's hawk nest sites near Grant Line Canal temporary barrier site



Old River at DMC

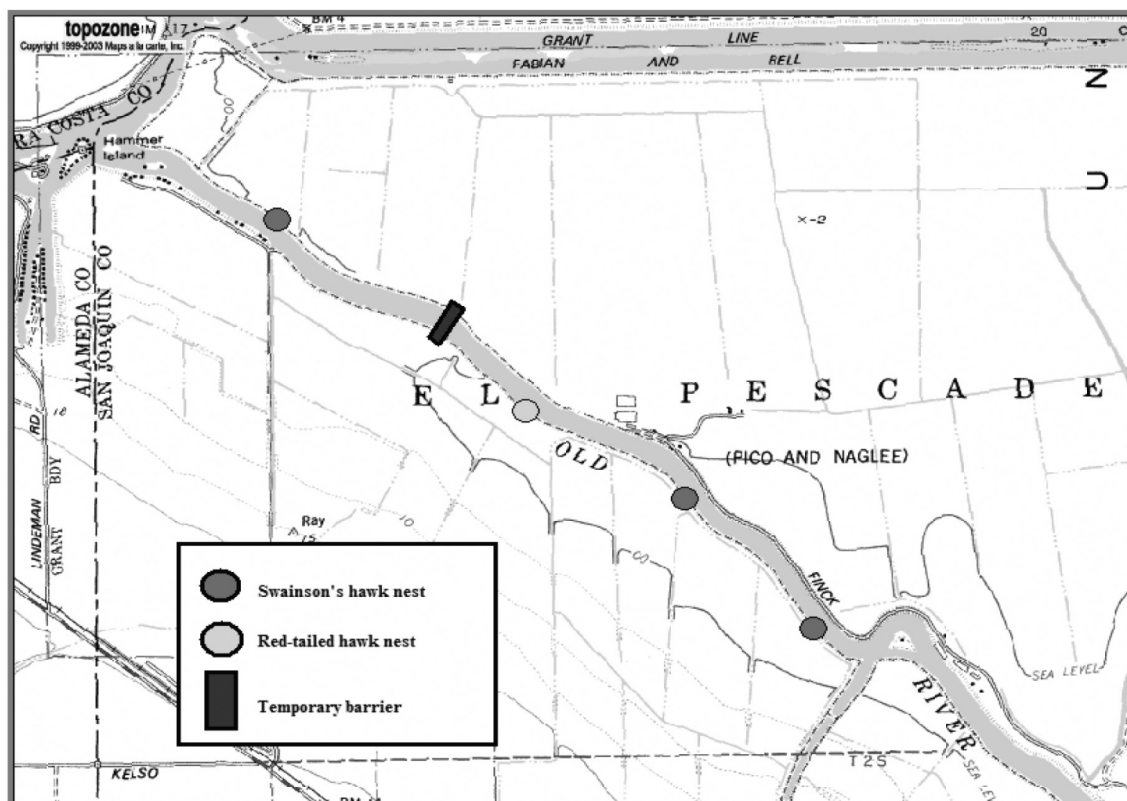
Three pairs of Swainson's hawks nested near the DMC barrier construction and storage sites, although one was well upstream of the sites (Figure 6-2). As with the Grant Line pair, all three pairs laid eggs later than the average time in an average year. Pair 1 (the southeastern-most nest site) nested in a traditional Swainson's hawk nest tree, an alder.

Two chicks were observed in the nest through the end of June, and are presumed fledged.

Pair 2 nested just southeast of the rock storage site. The nest tree was very unusual; an alder that was growing horizontally out of the side of the levee, not bigger than a large shrub. The nest was below the levee crown and only approximately 5 feet above the water, easily accessible by one of the many boaters who went past. To my knowledge, no one has observed/documentated another Swainson's hawk nest so close to the ground/water in the Central Valley, where most nest trees are very large. Neither the nest height nor close proximity to passing boats appeared to bother the pair, as they also hatched and raised two chicks that were observed through the end of June, and are also presumed fledged.

Pair 3 nested in a large pine tree downstream of the barrier site. The female was observed on the nest in brood (incubation) position through mid-June, but no chicks were ever observed. The nest was presumed failed.

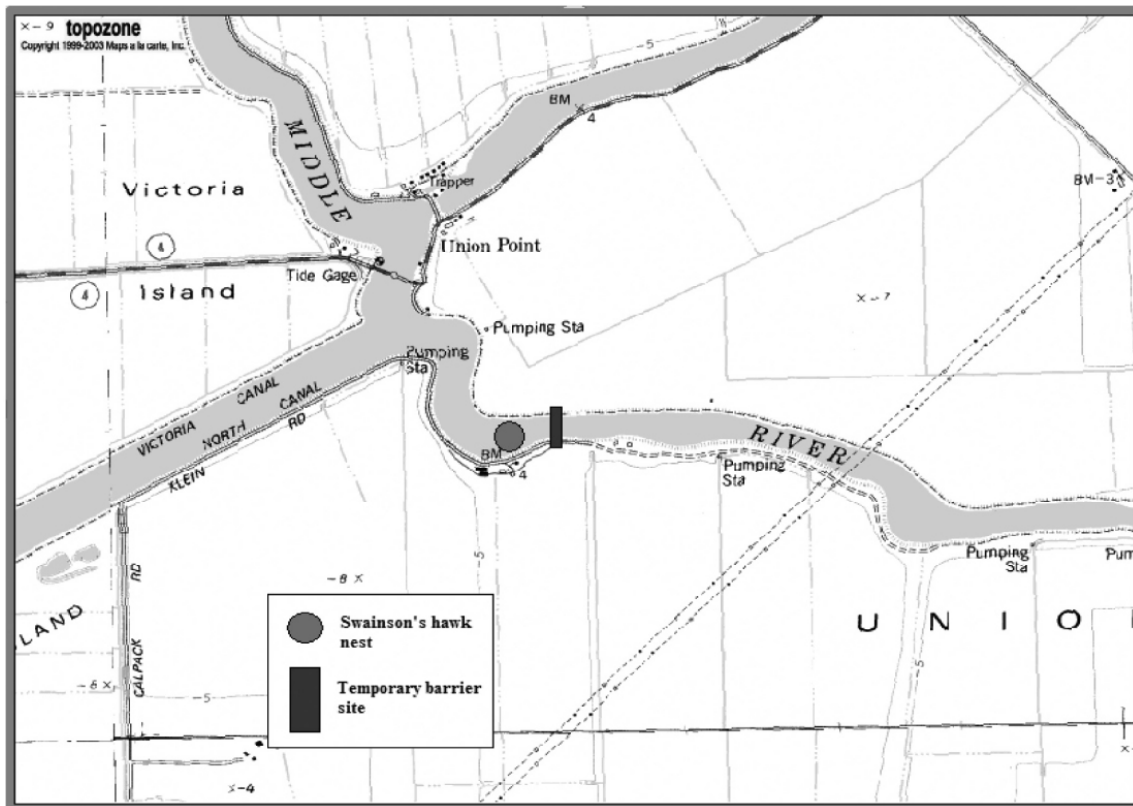
Figure 6-2. Swainson's hawk nest sites near the Old River DMC barrier site



Middle River

For the first year since the Department began installing the barrier on Middle River, a pair of Swainson's hawks successfully nested on an in-stream island 300 yards downstream of the barrier site (Figure 6-3). As with the other pairs monitored, the birds were late nesters, with a single chick hatching about June 8. The birds were still doing well by the end of June, and the chick is presumed fledged.

Figure 6-3. Swainson's hawk nest site near the Middle River Barrier



Head of Old River

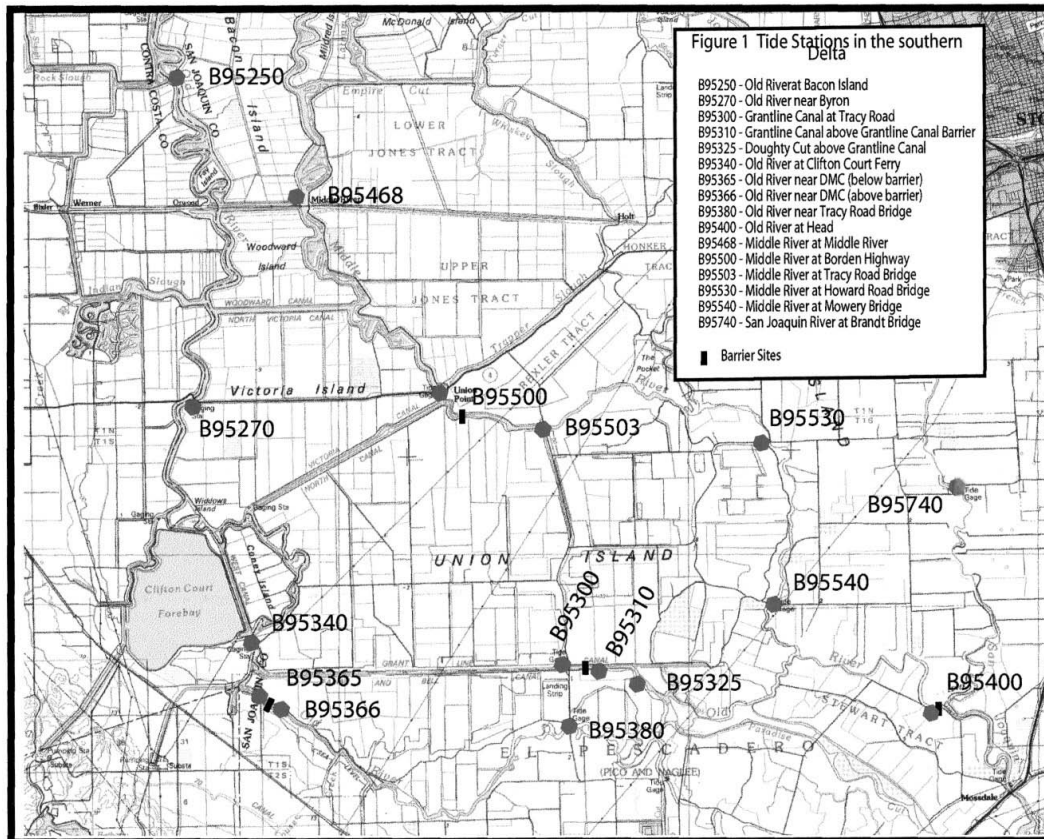
The Head of Old River Fish Barrier was not installed, so no project monitoring was completed for the site. A pair of Swainson's hawks that nest in the oak tree just downstream of the barrier on Old River and a pair that nest in the large cottonwood downstream of the barrier on the San Joaquin River were both present during DFG census surveys.

None of the nesting Swainson's hawks monitored at or around the barrier construction sites appeared to be impacted by construction activities.

Chapter 7. Water Elevations

The 2005 water elevation monitoring program included operation and maintenance of sixteen tide gauging stations near the barriers as shown in Figure 7-1. The 2005 monitoring program covers the period from January 2005 through December 2005, where stage is monitored at various stations with remote sensors.

Figure 7-1. Tide stations in the Southern Delta

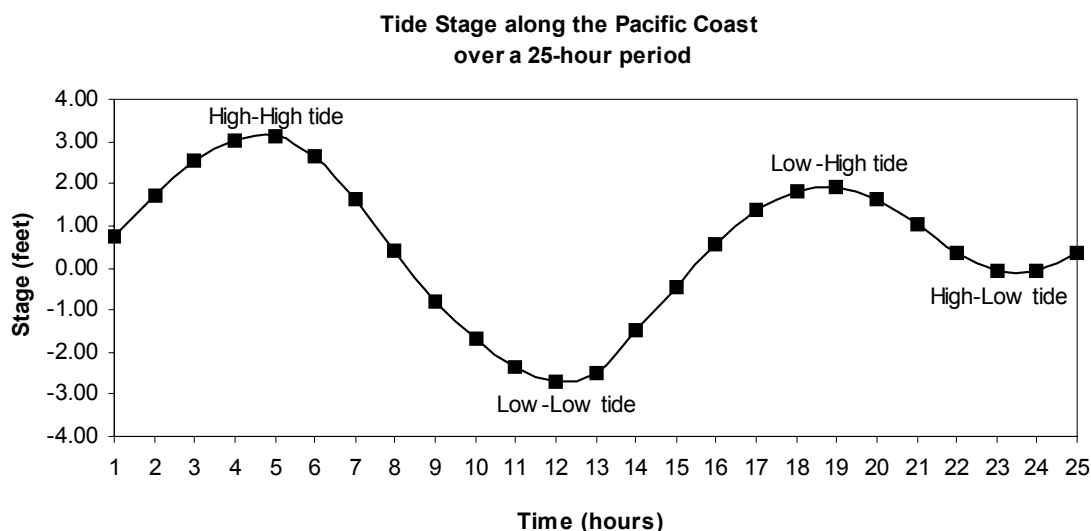


Instrumentation recorded water surface elevation daily at fifteen-minute intervals. Later, the data records were retrieved and downloaded to a computer for subsequent analysis.

Data collected at these stations were used to determine effects of the barriers on the water surface elevations and circulation patterns in the South Delta. Circulation patterns are estimated using the water surface elevation data as an input to the hydrologic mathematical model (DWRS2). Results of the model can be found elsewhere in this report.

Tides along the Pacific Coast exhibit a cycle of two high and two low tides over an approximately 25-hour period (Figure 7-2). These cycles vary in height throughout the day. Two elements make up a typical tidal curve.

- The tidal range is the difference between the highest and lowest tidal elevations.
- The daily inequality is the difference between the heights of successive high or low tides and the time between corresponding high or low stands of sea level.

Figure 7-2. Tide stage variation over a 25-hour cycle

A biweekly pattern of spring and neap tides is overlaid on top of the daily pattern. Additional patterns occur at longer intervals throughout the year.

Typically, farmers in the south Delta encounter pumping difficulties due to low water elevations during the irrigation season. One objective of the Old River at Tracy, Middle River, and Grant Line Canal barriers is to improve water elevations for agricultural diversions. This goal is achieved by installing barriers with culverts that restrict flow in the downstream direction during (receding) ebb tides, resulting in increased water levels upstream of the barrier. During periods of increasing (flood) tides, the open flap gates allow flow in the upstream direction. Sometimes during high flood tides water also flows over the barrier, thereby further increasing water level upstream of the barrier. The increasing tide replenishes water being lost or diverted for agriculture and will maintain higher water levels during the next receding tide.

The agricultural barriers are constructed from rock with flap-gated culverts to allow flow in the upstream direction. Design of the three barriers varies slightly due to differences in upstream channel geometry.

The following are highlights of barrier installation effects:

- At low tide, water surface elevation upstream of the barrier is raised, but the elevation downstream remains nearly the same.
- Extreme high tide water surface elevations upstream of the barrier may be slightly delayed and reduced due to energy losses through the culverts.
- During ebb tides, culvert flap gates seal and retain water behind the barriers.

Middle River Barrier

The Middle River Barrier is constructed to an elevation of +3.0 feet National Geodetic Vertical Datum (NGVD) and has six 48-inch diameter culverts. The center weir is 140 feet wide and constructed to an elevation of +1.0 foot NGVD (Figure 7-3). The center portion of the barrier is removed seasonally, while the culverts and the abutments remain in place year-round. (Three culverts are located in the north abutment and three culverts are located in the south abutment.)

The installation of Middle River (MR) barrier started on May 10 and was completed on May 17, 2005. The flap gates were tidally operational until November. For the 2005 operation, all three agricultural barriers were allowed to remain until November. The MR barrier removal work began on November 7, and was fully removed on November 9.

Water level monitoring is conducted at two nearby tide recording stations, B95500 downstream of this barrier at Borden Highway (Highway 4) and at B95503 just upstream of the barrier.

Figure 7-4 shows the mean monthly high tides and mean monthly low tides upstream and downstream of the Middle River barrier from January 2005 to December 2005. The barrier was in operation between May and November 2005. Figure 7-4 shows an increase in mean monthly low water levels of one and one half to about one foot on the upstream end of the barrier from May through October. This is a positive effect for irrigators.

Figure 7-3. Middle River barrier profile

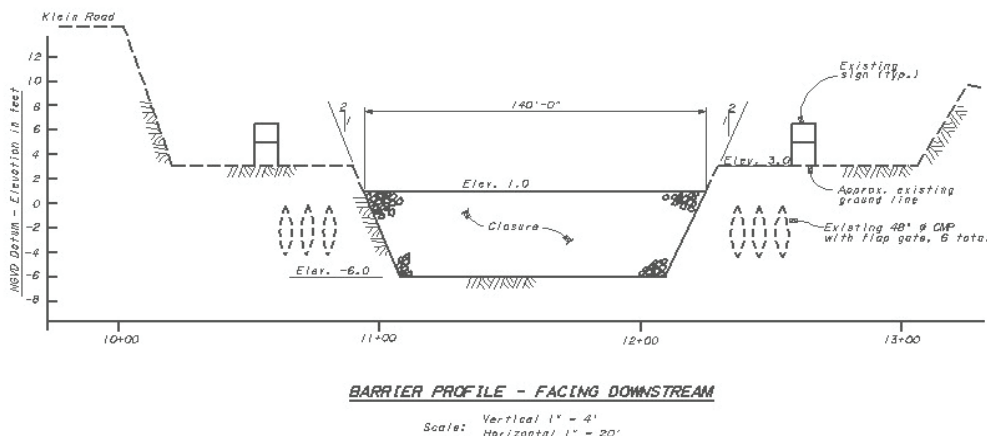
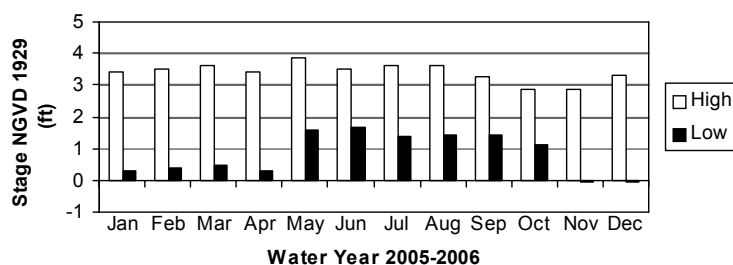
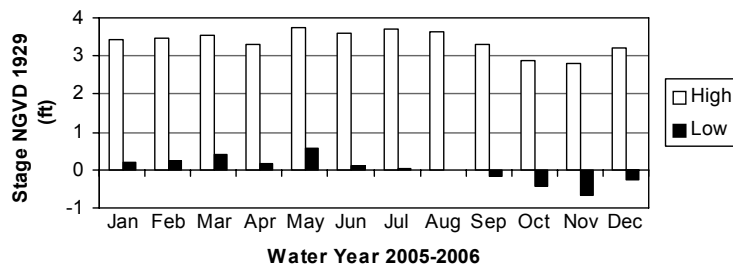


Figure 7-4. Water levels upstream and downstream of Middle River barrier

**Mean Monthly High and Low Tide at B95503
Upstream of Middle River Barrier**



**Mean Monthly High and Low Tides at B95500
Downstream of Middle River Barrier**



Old River at Tracy

The Old River at Tracy (ORT) barrier is constructed to an elevation of +4.0 feet NGVD and has nine 48-inch diameter culverts. The center weir is 75 feet wide and constructed to an elevation of +2.0 feet NGVD (Figure 7-5). The whole barrier structure is removed seasonally.

The ORT barrier was installed between May 9 and June 6, 2005. The flap gates were operational until early November when the barrier was removed. The barrier removal work began on November 8, and was fully removed on November 30, 2005.

Water level monitoring is conducted at two nearby tide stations, (1) B95365, downstream of the ORT barrier; and (2) B95366 upstream of the barrier. In 2005, both stations experienced an ongoing communication problem between the river and the stilling well resulting in an unreliable data for a certain periods of time at both locations. Station B95365 during the month of February reported 15 days of reliable data, however, during the months of March through June; the data collected was not reliable. In July, the station recorded only 12 days of good data during that month. All averages used in the plot were based on reliable data only. Station B95366 on the upstream side of the barrier reported 16 days of good data during the month of January but the month of February had only unreliable data. In March, the station recorded 22 days of good data, but April had the same fate as February. May recorded 15 days of good data, but June, July, and August had unreliable data reported. In December, only six days of reliable data was recorded. Figure 7-6 shows stages upstream and downstream of the Old River at Tracy barrier from April 2005 to November 2005, when the barrier was operational. Figure 7-6 shows an increase in mean monthly low water levels of more than 1.0 foot for September and October on the upstream end when the barrier was operational. The months of June, July and August likely had an increase in water level based on previous year's reporting but it could not be plotted because of the recorder's mishaps.

Figure 7-5. Old River at Tracy barrier profile

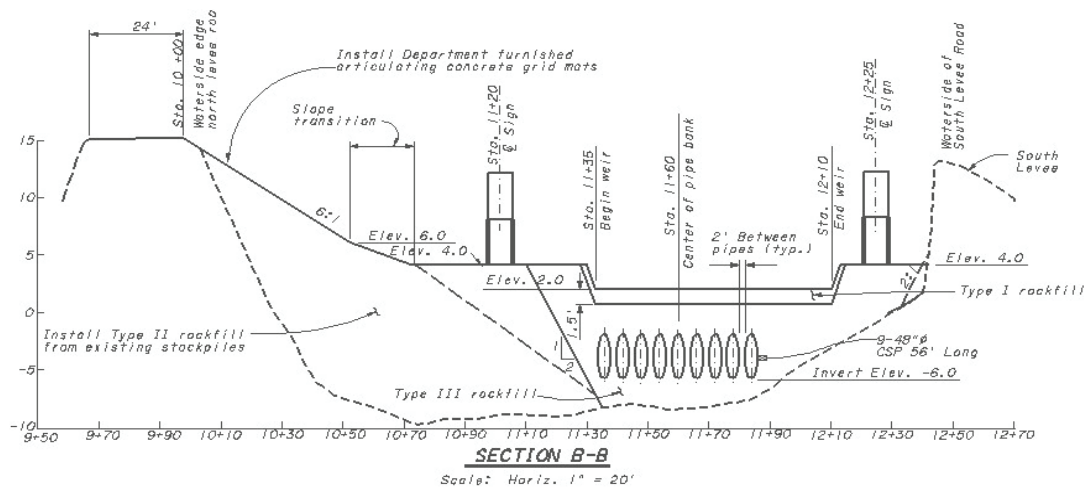
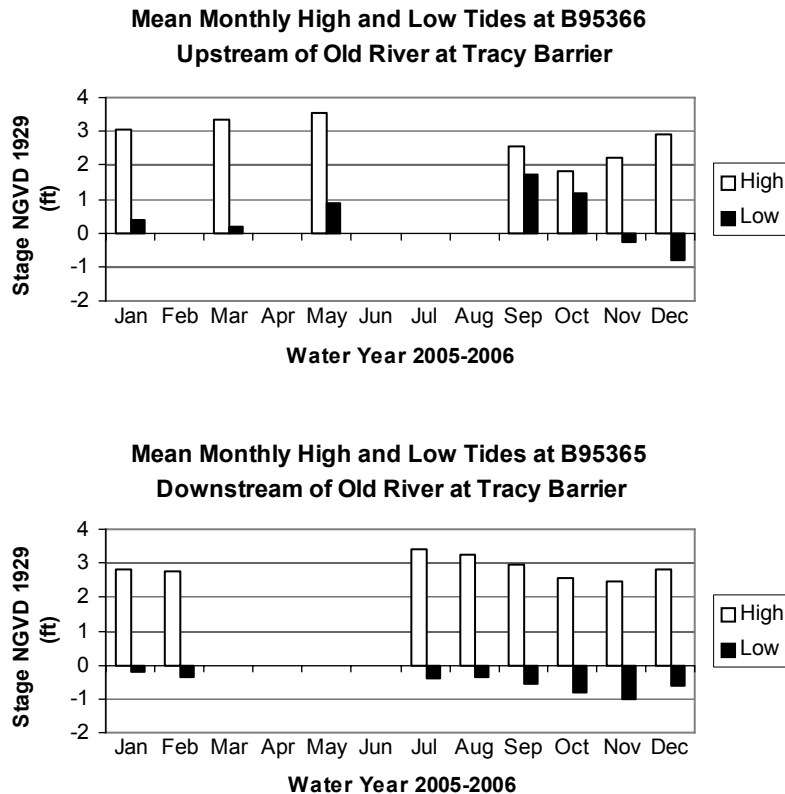


Figure 7-6. Water levels upstream and downstream of Old River at Tracy barrier

Grant Line Canal Barrier

The Grant Line Canal (GLC) barrier is constructed to an elevation of +4.0 NGVD and also has six 48-inch diameter culverts at the southern abutment of the barrier. The center weir is 140 feet wide and constructed to an elevation of +1.0 foot NGVD. In 2005, a 10 foot wide weir was operated on the southern abutment and the flashboards were adjusted on July 14 and September 14 to allow delta smelt passage (Figure 7-7). The culverts, fish passage weir and the southern abutment of the Grant Line Canal barrier are designed to remain in the channel year round. This will have less disruptive effects to the Swainson's hawk during the construction in spring.

The GLC barrier was installed between May 2 and July 18, 2005. Six flap gates were tied open till July 14 the closure day of the middle portion of the barrier. After July 14, the flap gates resumed normal tidal operation until early November when the barrier was removed. The barrier removal work began on November 7, and was fully removed on December 30, 2005.

Water level monitoring is conducted at two nearby tide recording stations: (1) B95300 just downstream of the barrier, this station reported 10 days of missing data during the month of July and four days of missing data during the month of October. (2) B95325 Doughty Cut upstream of the barrier.

Figure 7-8 shows stages upstream and downstream of the GLC barrier from January 2005 to December 2005. Figure 7-8 shows an increase in mean monthly low water levels of slightly less than 2.0 feet in July, greater or equal to 2.0 feet in August and September and slightly more than one foot in October.

Figure 7-7. Grant Line Canal barrier profile

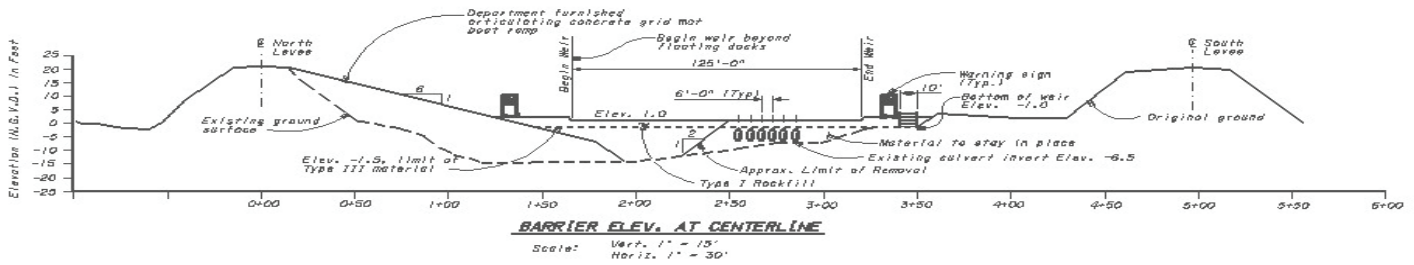
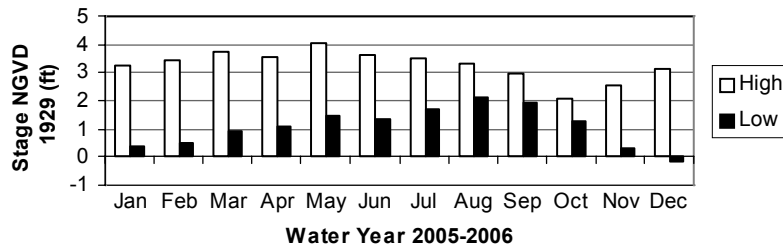
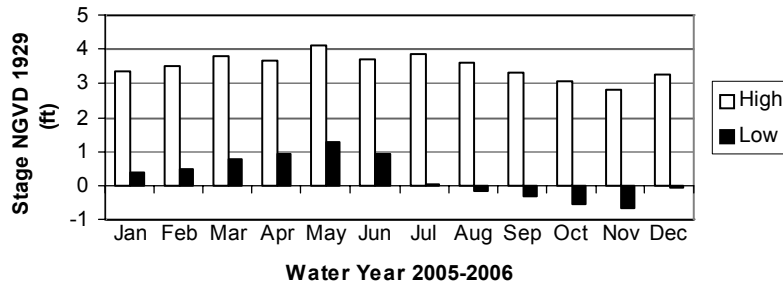


Figure 7-8. Water levels upstream and downstream of Grant Line Canal Barrier

Mean Monthly High and Low Tides at B95325
Doughty Cut Upstream of Grant Line Canal
Barrier



Mean Monthly High and Low Tides at B95300
Downstream of Grant Line Canal Barrier



Old River at Head Barrier

The head of Old River barrier (HORB) is designed as a fish barrier to prevent San Joaquin River Chinook Salmon Smolt from migrating down through Old River toward the Central Valley Project and State Water Project export facilities. The spring HORB was originally designed to withstand a San Joaquin River flow of about 3,000 cfs. Through the years, the design and installation of the HORB has been revised on several occasions to accommodate different needs. Typically, the barrier design includes two versions. A “low-flow” barrier would be built to a height of ten feet mean sea level (MSL) when San Joaquin River target flows are below 7,000 cfs. A “high-flow” barrier would be built to a height of 11 feet MSL for San Joaquin River target flows of 7,000 cfs and above and additional material would be placed to raise the abutments to 13 feet MSL. Both barrier versions are equipped with six 48-inch diameter operable culverts and an

overflow weir back-filled with clay. In 2005, the spring HORB was not constructed due to high flows on the San Joaquin River.

The fall HORB barrier was installed between September 19, 2005 and September 30, 2005. Barrier removal started on November 7 and was completed by November 15. It was constructed to an elevation of +4.0 feet NGVD and had six 48-inch diameter culverts (Figure 7-9). Figure 7-10 shows water levels in Old River approximately 1000 yard below the Head of Old River barrier during the three month of operation of the fall HORB, the mean monthly low level was the lowest during the month of November an elevation of approximately 1.0 foot NGVD and a maximum of two feet during the month of September.

Figure 7-11 shows water level at station B95420 the intake structure of Tom Paine Slough, the mean monthly low level dipped below zero during the month of December and was well above 1 foot during the period from April through October. Figure 7-11 also shows station B95421, Tom Paine Slough above the intake structure. This station reported unreliable or missing data during the month of June and 15 out of 31st days during the month of July. Averages presented in the plot during the month of July are based on good data only. Figure 7-11 also shows station B95425, Tom Paine Slough at Pescadero Pump Plant #6. This station was reactivated in April 2005, however, data collected in April and May had no verifiable datum and it was omitted.

Figure 7-9. Fall head of Old River barrier profile

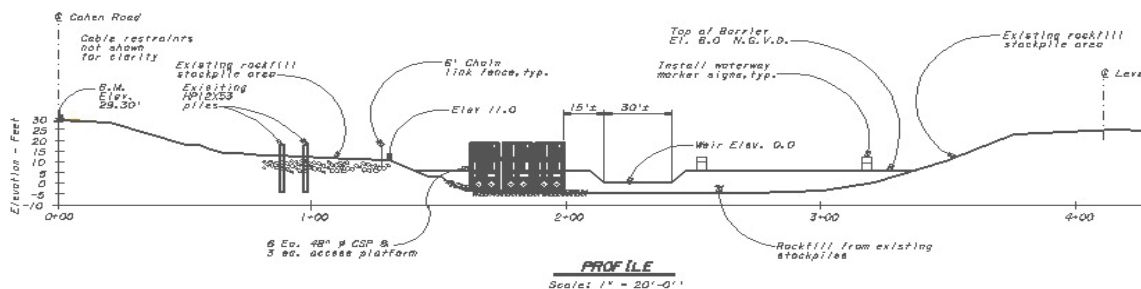


Figure 7-10. Water Levels downstream of Head of Old River Barrier

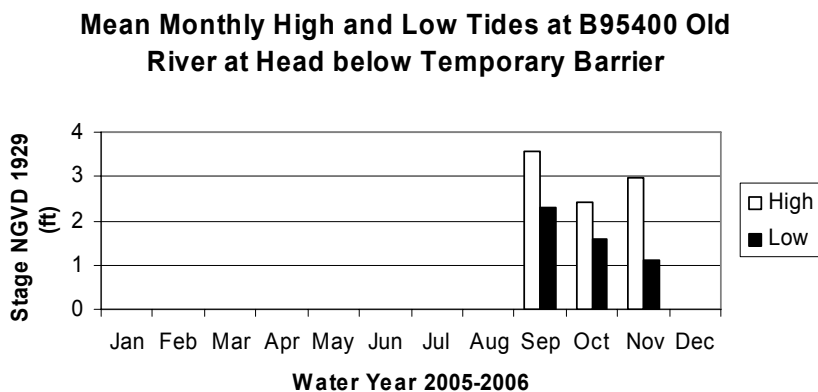
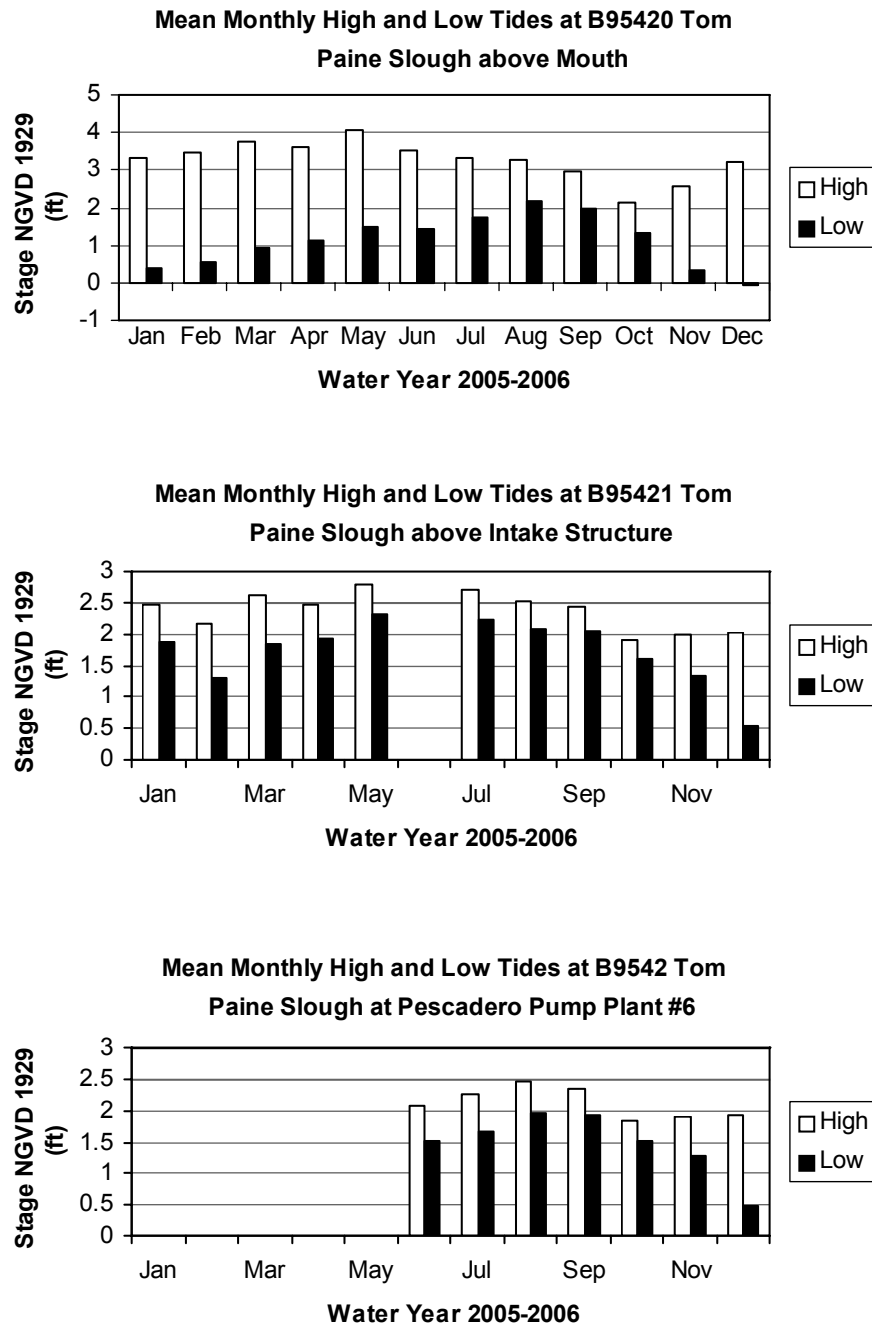


Figure 7-11. Water Levels at Tom Paine Slough above Mouth and above the Intake Structure and at Pump Plant #6



Chapter 8. Weekly Water Quality Sampling

Introduction

During the spring, summer and fall of 2005, four temporary rock barriers were installed in the South Delta as part of the South Delta Temporary Barriers Project. DWR continued its weekly water quality sampling program to evaluate the potential impacts of barrier installations and operations upon South Delta water quality and for compliance with the Central Valley Regional Water Quality Control Board permit. The sampling program commenced on May 3rd and was completed on December 6th. The four barriers were all installed on or after May 12th and removed by November 15th. Barrier installations were scheduled for April 1st, but were not installed until May because of high San Joaquin River flows. The Old River at Head barrier was not constructed in the spring as a result of high flows.

In addition, continuous monitoring to evaluate water quality impacts of barrier installations and operations in the South Delta was continued in 2005. This program was established for two reasons: first to determine the feasibility of collecting reliable time-series water quality data as opposed to weekly grab sampling data and second, to develop a dynamic understanding of water quality conditions affected by barrier installations, barrier operations, reservoir releases, forebay gate operations, State Water Project (SWP) and Central Valley Project (CVP) pumping operations, agricultural pumping and drainage, municipal effluent loading, hydrology, tidal fluctuations, meteorological conditions, Delta inflows as well as other variables.

Weekly Water Quality Sampling

Sites

This report presents data from ten sampling sites: one on the downstream side of each barrier, one on the upstream side of each barrier, excluding the Old River at Head, and an additional site located further upstream on each of the main river channels (Old River, Middle River, and Grant Line Canal). Figure 8-1 identifies the location of the ten water sampling sites.

Barrier Locations

The Middle River barrier is upstream of the confluence of Middle River, Trapper Slough, and North Canal. The Old River near Delta Mendota Canal (DMC) barrier is eight miles northwest of the town of Tracy and about a mile east of the DMC intake at the Tracy Pumping Plant. The Old River at Head barrier is immediately downstream of the Old and San Joaquin River split. The Grant Line Canal (GLC) barrier is located approximately 400 feet upstream of the Tracy Road Bridge at the east end of the GLC. Figure 8-1 shows the location of the four temporary barriers.

The Middle River, Old River at DMC, and Grant Line Canal barriers were installed to improve water circulation and to increase and stabilize water levels in the South Delta during the agricultural irrigation season. The Old River at Head barrier was constructed to increase net downstream flows in the lower San Joaquin River to aid salmon smolt outmigration through the Delta to the Pacific Ocean.

Sampling Methods

Water sampling was conducted every Tuesday morning between 5:00 AM and 9:00 AM for the entire operational period of the barriers. Channel water was tested at the ten sites using field instruments for temperature, dissolved oxygen, specific electrical conductivity and turbidity. Field equipment used included YSI-63 and YSI-85 handheld units that measured water temperature, dissolved oxygen, and specific conductance, a HACH modified Winkler titration kit to measure dissolved oxygen concentrations, and a HACH 2100P turbidimeter.

Every other Tuesday, filtered and unfiltered (turbidity) samples were collected at the ten sites for analysis at Bryte Lab. Constituents tested for were dissolved ammonia, dissolved nitrite + nitrate, dissolved organic nitrogen, dissolved orthophosphate, turbidity, chlorophyll *a*, and pheophytin *a*.

Weekly water quality data collected at each site is shown in Table 8-1.

Figure 8-1. Map of discrete water quality sites and temporary barrier locations

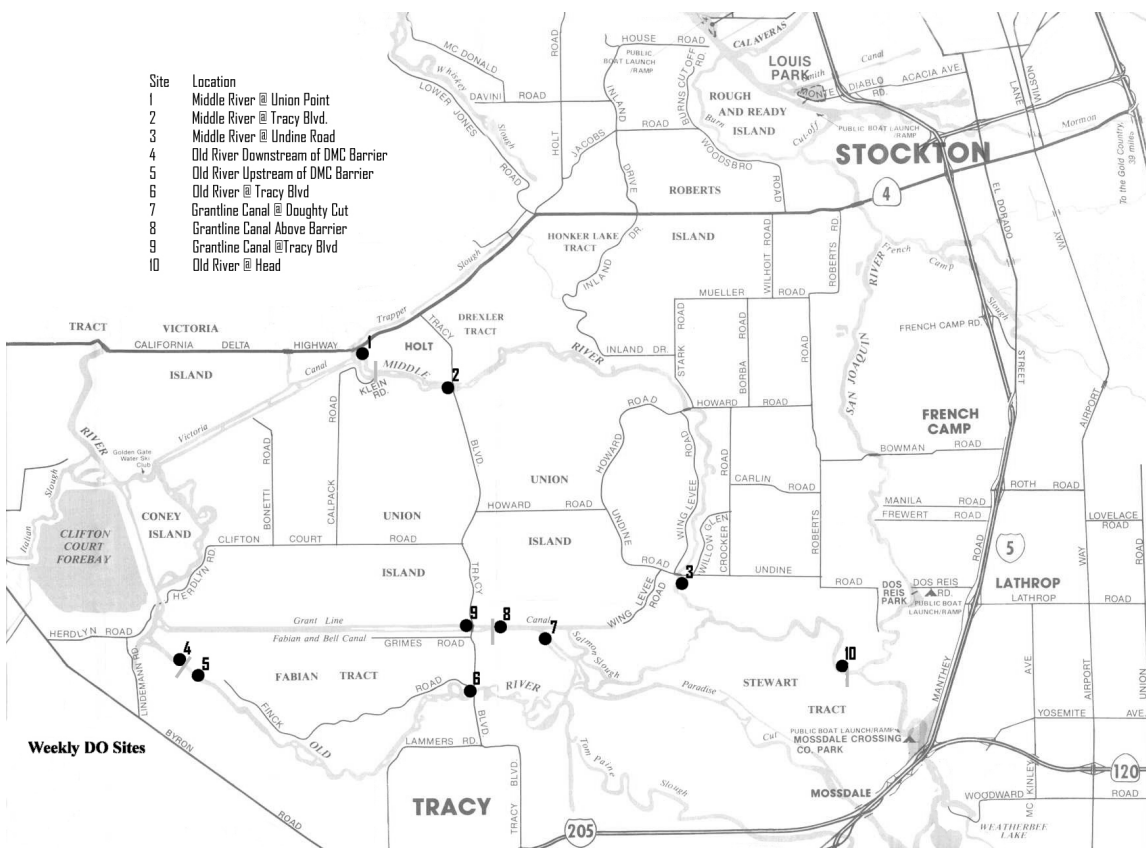


Table 8-1. Sampling methods and frequency of the water quality constituents measured at each of the 10 weekly water quality sampling sites

Constituent	Sampling Method		Sampling Frequency
	Field Instrument	Lab Method ¹	
Water Temperature	YSI-63 or YSI-85	N/A	Weekly
Dissolved Oxygen	YSI-85 and HACH Modified Winkler Titration Kit	N/A	Weekly
Specific Electrical Conductivity	YSI-63 or YSI-85	N/A	Weekly
Turbidity	HACH 2100P Turbidimeter	EPA 180.1	Weekly (alternates between field and lab)
Dissolved Ammonia	N/A	EPA 350.1	Bi-Monthly
Dissolved Nitrite + Nitrite	N/A	Modified Standard Method 4500-NO ₃ -F	Bi-Monthly
Dissolved Organic Nitrogen	N/A	EPA 351.2	Bi-Monthly
Dissolved Orthophosphate	N/A	Modified EPA 365.1	Bi-Monthly
Chlorophyll <i>a</i>	N/A	Standard Method 10200 H, Spectrometric Determination of Chlorophyll	Bi-Monthly
Pheophytin <i>a</i>	N/A	Standard Method 10200 H, Spectrometric Determination of Chlorophyll	Bi-Monthly

1. Dissolved Nitrite + Nitrate and Dissolved Orthophosphate Lab Methods Modified by DWR-Bryte Lab

Middle River Barrier

The Middle River barrier was constructed on May 12th, 2005 and removed on November 8th, 2005. Monitoring of the Middle River was conducted at three sites: 1) the Undine Road Bridge (site 3) just downstream of the split between Middle and Old Rivers, 2) Tracy Road Bridge over Middle River (site 2), and 3) at Union Point (site 1) immediately downstream of the Middle River barrier. Figure 8-2 shows the weekly water quality field and lab data for the Middle River. In addition, the data are displayed in Tables 8-2 through 8-4, which show pre-barrier, during and post-barrier sampling events.

Mean water temperatures in Middle River ranged from 17.81°C (Undine Road) to 19.58°C (Union Point). Water temperatures tended to follow season patterns: temperatures began to rise in mid-spring and continued to increase until mid-summer. Temperatures then gradually declined in late summer and throughout fall. In addition to localized differences, variability in water temperature data for the Middle River could be due to differences in sampling times. The highest recorded temperature was 25.1°C on July 26th at Tracy Road, and the lowest was 6.6°C on December 6th at Undine Road.

Figure 8-2. Middle River - Weekly Water Quality Data

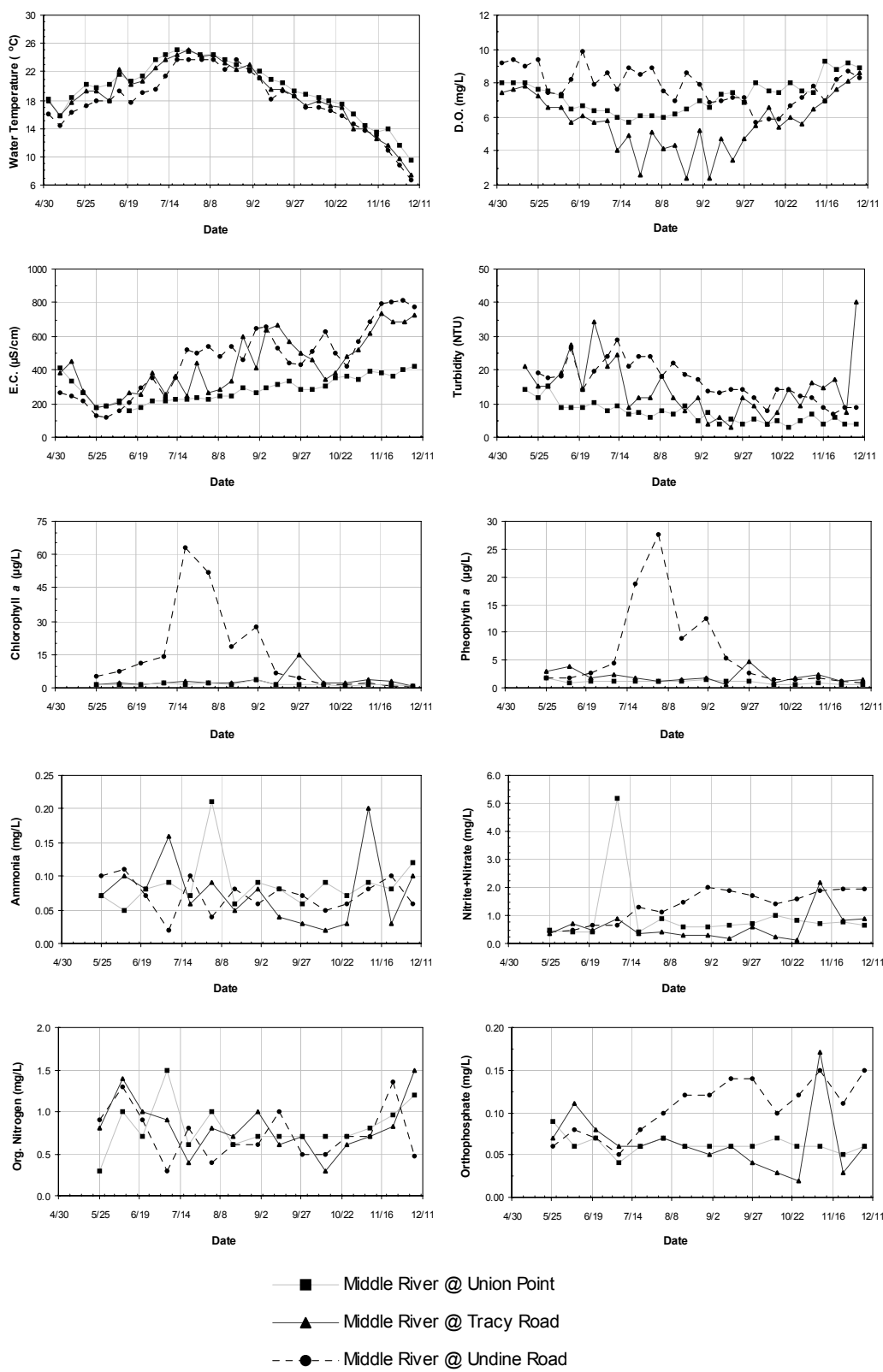


Table 8-2. Middle River at Union Point: 2005 Water Quality Data

MIDDLE RIVER @ UNION POINT (B9D75351292) South Delta Temporary Barriers Project - 2005 Weekly Water Quality Sampling Data												
DATE & TIME (mm/dd/yy PST)	FIELD READINGS					BRYTE LAB RESULTS						
	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
5/3/05 6:22	18.1	8.0	407		4.90							
5/10/05 5:20	15.9	8.0	331		6.71							
5/17/05 5:15	18.4	8.0	268	14.0	5.40							
5/25/05 5:18	20.2	7.6	172		7.51	0.07	0.45	0.3	0.09	12.0	1.29	1.70
5/31/05 5:05	19.8	7.5	183	15.4	4.90							
6/8/05 5:35	20.1	7.2	220		6.73	0.05	0.40	1.0	0.06	9.0	1.12	0.89
6/14/05 5:21	21.7	6.5	159	8.8	4.12							
6/21/05 5:21	20.7	6.7	178		6.95	0.08	0.40	0.7	0.07	9.0	1.29	1.22
6/28/05 5:21	21.4	6.4	212	10.4	3.80							
7/6/05 5:30	23.7	6.4	220		7.00	0.09	5.20	1.5	0.04	8.0	1.94	1.07
7/12/05 5:24	24.3	6.0	229	9.4	4.33							
7/19/05 5:20	25.0	5.7	222		6.05	0.07	0.44	0.6	0.06	7	1.76	1.13
7/26/05 5:17	24.8	6.1	232	7.4	3.28							
8/2/05 5:35	24.5	6.1	227		5.20	0.21	0.90	1.0	0.07	6.0	2.06	1.07
8/9/05 5:43	24.4	6.0	242	8.0	4.38							
8/16/05 5:00	23.8	6.2	250		4.80	0.06	0.56	0.6	0.06	7.0	1.46	1.33
8/23/05 5:30	23.0	6.5	298	9.1	3.82							
8/31/05 5:28	22.4	7.0	265		4.10	0.09	0.60	0.7	0.06	5.0	3.42	1.63
9/6/05 5:47	22.0	6.6	293	7.2	4.10							
9/13/05 6:00	20.8	7.4	313		3.48	0.08	0.67	0.7	0.06	4.0	1.48	1.17
9/20/05 5:38	20.4	7.4	335	5.4	4.35							
9/27/05 6:00	19.2	6.9	282		3.00	0.06	0.70	0.7	0.06	4.0	1.79	1.21
10/4/05 5:45	18.7	8.0	286	5.4	3.60							
10/12/05 5:42	18.4	7.5	306		2.72	0.09	1.00	0.7	0.07	4.0	1.30	0.68
10/18/05 5:00	17.9	7.4	356	4.7	3.70							
10/25/05 5:45	17.5	8.0	366		2.74	0.07	0.82	0.7	0.06	3.0	1.09	0.62
11/1/05 5:39	16.1	7.5	346	4.9	3.62							
11/8/05 5:54	14.5	7.4	394		2.24	0.09	0.72	0.8	0.06	7.0	1.44	1.02
11/15/05 6:35	13.4	9.3	381	4.0	3.85							
11/22/05 10:34	14.0	8.8	364		3.56	0.08	0.78	1.0	0.05	6.0	1.22	0.65
11/29/05 7:02	11.7	9.2	405	3.9	3.08							
12/6/05 6:19	9.6	8.9	417		2.05	0.12	0.63	1.2	0.06	4.0	0.52	0.48

= Middle River barrier in place from 5/12/05 - 11/8/05

	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Maximum	25.00	9.30	417.00	15.40	7.51	0.21	5.20	1.50	0.09	12.00	3.42	1.70
Minimum	9.60	5.70	159.00	3.94	2.05	0.05	0.40	0.30	0.04	3.00	0.52	0.48
Mean	19.58	7.26	286.22	7.87	4.38	0.09	0.95	0.81	0.06	6.33	1.55	1.06
Range	15.40	3.60	258.00	11.46	5.46	0.16	4.80	1.20	0.05	9.00	2.90	1.22
Standard Deviation	3.99	0.97	75.50	3.46	1.44	0.04	1.19	0.29	0.01	2.47	0.64	0.35
Sample Variance	15.94	0.94	5,700.76	11.94	2.06	0.00	1.41	0.08	0.00	6.10	0.41	0.12
Standard Error	3.41	0.39	54.69	2.43	0.41	0.04	1.23	0.22	0.01	2.38	0.67	0.29
Median	20.15	7.39	284.00	7.40	4.10	0.08	0.67	0.70	0.06	6.00	1.44	1.07
Mode	18.40	8.00	220.00	-	4.90	0.09	0.40	0.70	0.06	4.00	1.29	1.07
Count	32	32	32	15	32	15	15	15	15	15	15	15
Confidence Interval (95%)*	1.38	0.34	26.16	1.75	0.50	0.02	0.60	0.14	0.01	1.25	0.33	0.18

* Mean (μ) for Temperature = 19.58; 95% Confidence interval is 19.58 ± 1.38 or $18.20 \leq \mu \leq 20.96$. This means the interval between 18.20 and 20.96 has a .95 probability of containing μ .

Table 8-3. Middle River at Tracy Road: 2005 Water Quality Data

MIDDLE RIVER @ TRACY ROAD (B9D75291273) South Delta Temporary Barriers Project - 2005 Weekly Water Quality Sampling Data												
DATE & TIME (mm/dd/yy PST)	FIELD READINGS					BRYTE LAB RESULTS						
	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
5/3/05 6:50	18.0	7.4	387		4.00							
5/10/05 5:52	15.7	7.6	448		6.90							
5/17/05 5:32	17.6	7.8	271	20.9	5.75							
5/25/05 5:41	19.2	7.2	181		7.60	0.07	0.34	0.8	0.07	15.0	1.34	2.93
5/31/05 5:25	19.3	6.6	182	15.3	5.58							
6/8/05 6:00	18.0	6.6	210		6.10	0.10	0.73	1.4	0.11	19.0	2.35	3.93
6/14/05 5:45	22.3	5.7	260	27.3	4.30							
6/21/05 6:06	20.2	6.1	254		6.21	0.08	0.47	1.0	0.08	14.0	1.43	1.79
6/28/05 5:42	20.6	5.7	385	34.5	4.05							
7/6/05 6:10	22.5	5.8	255		6.24	0.16	0.88	0.9	0.06	21.0	1.98	2.32
7/12/05 5:37	23.7	4.0	367	24.6	3.80							
7/19/05 5:42	24.4	4.9	244		6.30	0.06	0.36	0.4	0.06	9	2.78	1.75
7/26/05 5:33	25.1	2.6	439	11.9	4.00							
8/2/05 6:12	24.1	5.1	268		5.32	0.09	0.39	0.8	0.07	12.0	2.21	1.18
8/9/05 5:59	24.5	4.1	283	18.0	4.80							
8/16/05 5:22	23.3	4.3	331		5.21	0.05	0.29	0.7	0.06	12.0	2.40	1.48
8/23/05 6:00	22.3	2.4	594	7.7	4.80							
8/31/05 7:35	22.9	5.2	416		5.00	0.08	0.27	1.0	0.05	12.0	3.63	1.64
9/6/05 6:00	21.2	2.4	635	4.0	4.10							
9/13/05 6:19	19.6	4.7	662		4.58	0.04	0.15	0.6	0.06	6.0	1.71	0.58
9/20/05 6:00	19.4	3.5	565	2.8	3.90							
9/27/05 6:22	18.6	4.7	501		5.00	0.03	0.56	0.7	0.04	12.0	14.50	4.73
10/4/05 6:05	17.2	5.5	457	9.4	4.10							
10/12/05 6:12	17.8	6.6	341		3.02	0.02	0.22	0.3	0.03	4.0	1.97	0.81
10/18/05 5:19	17.3	5.4	387	7.2	3.63							
10/25/05 6:20	16.9	6.0	478		4.05	0.03	0.13	0.6	0.02	14.0	2.51	1.90
11/1/05 6:01	14.0	5.6	517	9.3	5.33							
11/8/05 6:18	14.0	6.5	616		2.60	0.20	2.20	0.7	0.17	16.0	3.74	2.43
11/15/05 7:10	12.6	7.0	739	14.6	3.85							
11/22/05 10:15	11.7	7.6	689		3.39	0.03	0.83	0.8	0.03	17.0	2.78	1.26
11/29/05 11:27	9.8	8.1	687	7.2	3.12							
12/6/05 6:45	7.5	8.6	727			0.10	0.86	1.5	0.06	40.0	0.96	1.44
= Middle River barrier in place from 5/12/05 - 11/8/05												
	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Maximum	25.10	8.60	739.00	34.50	7.60	0.20	2.20	1.50	0.17	40.00	14.50	4.73
Minimum	7.50	2.40	181.00	2.78	2.60	0.02	0.13	0.30	0.02	4.00	0.96	0.58
Mean	18.79	5.67	430.50	14.31	4.73	0.08	0.58	0.82	0.06	14.87	3.09	2.01
Range	17.60	6.20	558.00	31.72	5.00	0.18	2.07	1.20	0.15	36.00	13.54	4.15
Standard Deviation	4.43	1.64	170.97	9.18	1.20	0.05	0.52	0.32	0.04	8.27	3.25	1.13
Sample Variance	19.63	2.68	29,231.35	84.25	1.43	0.00	0.27	0.10	0.00	68.41	10.57	1.27
Standard Error	3.72	1.15	173.79	7.80	0.77	0.05	0.32	0.33	0.04	8.48	3.32	0.87
Median	19.25	5.70	401.50	11.90	4.58	0.07	0.39	0.80	0.06	14.00	2.35	1.75
Mode	18.00	6.60	387.00	-	4.00	0.03	-	0.70	0.06	12.00	2.78	-
Count	32	32	32	15	31	15	15	15	15	15	15	15
Confidence Interval (95%)*	1.54	0.57	59.24	4.64	0.42	0.03	0.26	0.16	0.02	4.19	1.65	0.57

* Mean (μ) for Temperature = 18.79; 95% Confidence interval is 18.79 ± 1.54 or $17.25 \leq \mu \leq 20.33$. This means the interval between 17.25 and 20.33 has a .95 probability of containing μ .

Table 8-4. Middle River at Undine Road: 2005 Water Quality Data

MIDDLE RIVER @ UNDINE ROAD (B9D75011230)
 South Delta Temporary Barriers Project - 2005 Weekly Water Quality Sampling Data

DATE & TIME (mm/dd/yy PST)	FIELD READINGS					BRYTE LAB RESULTS						
	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
5/3/05 7:30	16.0	9.2	265		6.20							
5/10/05 6:42	14.5	9.4	245		7.50							
5/17/05 6:25	16.3	9.0	215		6.90							
5/25/05 6:10	17.2	9.4	131		8.40	0.10	0.40	0.9	0.06	19	4.91	1.70
5/31/05 6:30	17.8	7.4	120	17.6	7.75							
6/8/05 6:50	17.8	7.4	154		8.10	0.11	0.45	1.3	0.08	18.0	7.16	1.82
6/14/05 6:38	19.3	8.2	207	26.3	6.20							
6/21/05 6:35	17.6	9.9	298		7.60	0.07	0.67	0.9	0.07	14.0	10.90	2.60
6/28/05 6:20	19.0	8.0	355	19.8	5.05							
7/6/05 6:16	19.6	8.6	233		6.38	0.02	0.62	0.3	0.05	24.0	14.30	4.38
7/12/05 6:15	21.4	7.6	352	29.0	4.00							
7/19/05 6:45	23.6	8.9	518		6.52	0.10	1.30	0.8	0.08	21.0	63.40	18.80
7/26/05 5:55	23.6	8.5	501	24.2	4.20							
8/2/05 6:00	23.6	8.9	536		5.97	0.04	1.10	0.4	0.10	24.0	52.10	27.60
8/9/05 5:47	23.8	7.5	485	18.0	4.51							
8/16/05 6:42	22.2	7.0	535		5.80	0.08	1.50	0.6	0.12	22.0	18.80	8.94
8/23/05 10:00	23.8	8.6	462	18.8	4.94							
8/31/05 6:00	22.0	7.9	650		5.25	0.06	2.00	0.6	0.12	17.0	27.60	12.60
9/6/05 5:53	21.1	6.9	655	13.8	4.35							
9/13/05 6:17	18.2	7.0	529		5.51	0.08	1.90	1.0	0.14	13.0	6.78	5.29
9/20/05 6:32	19.3	7.1	441	14.1	4.58							
9/27/05 7:20	18.5	7.1	432		5.15	0.07	1.70	0.5	0.14	14.0	4.22	2.55
10/4/05 6:00	16.9	5.7	506	11.9	3.90							
10/12/05 6:25	17.0	5.9	629		4.51	0.05	1.40	0.5	0.10	8.0	1.76	1.49
10/18/05 6:28	16.4	5.9	500	14.2	3.80							
10/25/05 7:05	15.9	6.7	426		4.75	0.06	1.60	0.7	0.12	14.0	1.25	1.49
11/1/05 7:00	14.7	7.1	564	12.1	3.72							
11/8/05 7:40	13.6	7.8	685		4.30	0.08	1.90	0.7	0.15	12.0	2.24	1.64
11/15/05 7:10	12.9	7.0	799	8.6	3.31							
11/22/05 7:25	10.9	8.2	807		2.83	0.10	1.97	1.4	0.11	7.0	0.89	1.04
11/29/05 8:13	8.8	8.7	813	8.9	3.38							
12/6/05 7:45	6.6	8.3	772		2.68	0.06	1.93	0.5	0.15	9.0	0.67	0.84

█ = Middle River barrier in place from 5/12/05 - 11/8/05

	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Maximum	23.80	9.91	813.00	29.00	8.40	0.11	2.00	1.35	0.15	24.00	63.40	27.60
Minimum	6.60	5.70	120.00	8.60	2.68	0.02	0.40	0.30	0.05	7.00	0.67	0.84
Mean	17.81	7.84	463.13	16.95	5.25	0.07	1.36	0.74	0.11	15.73	14.47	6.19
Range	17.20	4.21	693.00	20.40	5.72	0.09	1.60	1.05	0.10	17.00	62.73	26.76
Standard Deviation	4.30	1.08	202.82	6.25	1.56	0.02	0.58	0.31	0.03	5.56	19.24	7.82
Sample Variance	18.47	1.17	41,134.63	39.03	2.44	0.00	0.34	0.10	0.00	30.92	370.28	61.11
Standard Error	3.88	1.10	196.50	4.68	1.13	0.03	0.60	0.32	0.03	4.93	15.03	2.84
Median	17.80	7.85	492.50	15.90	5.00	0.07	1.50	0.70	0.11	14.00	6.78	2.55
Mode	23.60	7.00	-	-	6.20	0.10	1.90	0.90	0.12	14.00	-	1.49
Count	32	32	32	14	32	15	15	15	15	15	15	15
Confidence Interval (95%)*	1.49	0.37	70.27	3.27	0.54	0.01	0.29	0.16	0.02	2.81	9.74	3.96

* Mean (µ) for Temperature = 17.81; 95% Confidence interval is 17.81 ± 1.49 or 16.32 ≤ µ ≤ 19.30. This means the interval between 16.32 and 19.30 has a .95 probability of containing µ.

Dissolved oxygen (DO) concentrations in the Middle River at Tracy Road were low during the summer compared to the spring and fall, in part due to high water temperatures and low San Joaquin River flows. Figure 8-3 shows flow and specific conductance data for the San Joaquin River at Vernalis in 2005. DO concentrations at the Tracy Road site were consistently lower than the other two stations during the summer with, values ranging from 2.4 mg/L to 5.5 mg/L from

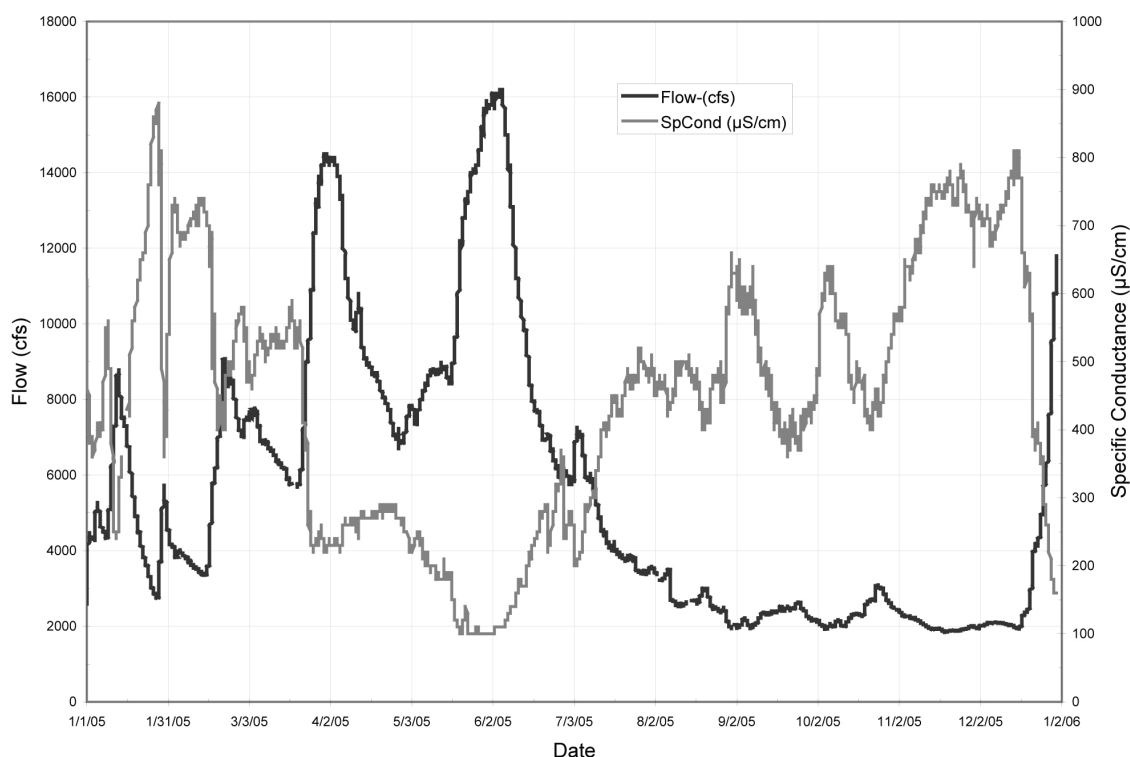
July 12th through October 4th. Ten field readings collected at Tracy Road were less than 5 mg/L. Undine Road and Union Point did not have any dissolved oxygen readings below 5.7 mg/L. The lowest DO reading was 2.4 mg/L on August 23rd and September 6th, both at Tracy Road. The highest DO reading was 9.9 mg/L on June 21st at Undine Road. Mean DO concentrations ranged from 5.67 mg/L at Tracy Road to 7.84 mg/L at Undine Road.

Specific electrical conductivity values in the Middle River were higher upstream at the Undine Road site than at the Union Point site. The greatest differences in upstream and downstream specific conductance values were observed from mid July through December. Differences in upstream and downstream specific conductance values are likely due to differences in San Joaquin River water and incoming tidal water from the Sacramento River. Specific conductance values were lowest during the spring and highest during the fall. Union Point specific electrical conductivity readings ranged from 159.0 to 417.0 $\mu\text{S}/\text{cm}$ and had a mean of 286 $\mu\text{S}/\text{cm}$. Comparatively, Tracy Road and Undine Road had means of 431 $\mu\text{S}/\text{cm}$ and 463 $\mu\text{S}/\text{cm}$, respectively. The minimum recorded value was 120.0 $\mu\text{S}/\text{cm}$ on May 31st, and the maximum-recorded value was 813 $\mu\text{S}/\text{cm}$ on November 29th, both at Undine Road.

Water clarity diminished upstream of the Middle River barrier as turbidity values were higher at the Tracy Road and Undine Road monitoring stations than at the Union Point site. Undine Road was the most turbid site in the Middle River with values ranging from 7.0 – 29 NTU and had a mean of 16.3 NTU. Turbidity readings at Undine Road tended to be higher in the summer relative to the other two sites. Union Point readings were consistently the lowest throughout the monitoring period ranging from 3.0 to 15.4 NTU with a mean of 7.1 NTU. Upstream of the barrier at Tracy Road, turbidity values ranged from 2.8 to 40 NTU with a mean of 14.6 NTU.

Algal biomass, as indicated by chlorophyll *a* concentrations, was higher upstream at the Undine Road site than at the downstream monitoring sites. Chlorophyll *a* levels began to increase in the early summer and continued to rise until mid summer, reaching a peak of 63.4 $\mu\text{g}/\text{L}$ on July 19th. After peaking, chlorophyll *a* levels declined sharply in late summer and fall, reaching a minimum of 0.67 $\mu\text{g}/\text{L}$ on December 6th. Overall, chlorophyll *a* at Undine Road averaged 14.5 $\mu\text{g}/\text{L}$. Measured chlorophyll *a* concentrations at Tracy Road and Union Point reached maximums of 14.5 $\mu\text{g}/\text{L}$ and 3.42 $\mu\text{g}/\text{L}$ on September 27th and August 31st, respectively. There were no noteworthy differences in chlorophyll *a* levels at the aforementioned stations, with averages of 1.55 $\mu\text{g}/\text{L}$ at Union Point and 3.09 $\mu\text{g}/\text{L}$ at Tracy Road.

When algae die, chlorophyll *a* degrades into byproducts. Pheophytin *a* is a degradation product of chlorophyll *a*. Pheophytin *a* concentrations were noticeably higher at the Undine Road site in comparison to the downstream sites, which would be expected based on the high chlorophyll *a* concentrations at Undine Road. Undine Road had a maximum recorded pheophytin *a* concentration of 27.6 $\mu\text{g}/\text{L}$ on August 2nd and had a mean of 6.2 $\mu\text{g}/\text{L}$. Measured pheophytin *a* concentrations in the Middle River at Union Point and Tracy Road were low compared to Undine Road with means of 1.06 $\mu\text{g}/\text{L}$ and 2.01 $\mu\text{g}/\text{L}$, respectively.

Figure 8-3. Flow and specific conductance in the San Joaquin River at Vernalis

Measured ammonia concentrations in the Middle River were similar throughout the spring, summer and fall. Except for a few occurrences ammonia concentrations at the three sites tracked well and did not show many differences. Mean ammonia values ranged from 0.07 to 0.09 mg/L. Ammonia concentrations ranged from a maximum of 0.21 mg/L recorded on August 2nd at Union Point to a minimum of 0.02 mg/L recorded on July 6th and October 12th, at Undine Road and Tracy Road, respectively.

Nitrite-Nitrate concentrations were greater upstream at the Undine Road site during the late summer and fall. The mean nitrite-nitrate concentration at Undine Road was 1.36 mg/L. Nitrite-nitrate concentrations at Union Point and Tracy Road were similar throughout the monitoring period, except for a maximum value of 5.20 mg/L that was recorded on July 6th at Union Point. Tracy Road had the lowest nitrite-nitrate concentration in the Middle River with an average of 0.58 mg/L.

Organic nitrogen values fluctuated throughout the monitoring period ranging from 0.30 to 1.50 mg/L and were higher in the spring and fall. The mean organic nitrogen concentration at Undine Road was 0.74 mg/L. Tracy Road had slightly higher organic nitrogen values with an average of 0.82 mg/L. Downstream of the barrier at Union Point, organic nitrogen concentrations were the similar to Tracy Road averaging 0.81 mg/L.

The Undine Road site tended to have higher orthophosphate values than the Union Point and Tracy Road sites throughout the summer and fall. Overall, orthophosphate concentrations at Undine Road averaged 0.11 mg/L with a maximum value of 0.15 mg/L recorded on November 8th. Orthophosphate values at Union Point and Tracy Road tracked relatively closely averaging 0.06 mg/L. Values ranged from 0.04 to 0.09 mg/L at Union Point and from 0.02 to 0.17 mg/L at Tracy Road.

Overall, some of water quality constituents measured in the Middle River showed differences between the stations (Union Point and Tracy Road) downstream and upstream of the barrier and the upstream station (Undine Road). Middle River at Undine Road had the highest specific electrical conductance, turbidity, chlorophyll *a*, pheophytin *a*, nitrite-nitrate, and orthophosphate values. There were also differences observed in dissolved oxygen, specific electrical conductance, and turbidity, at the monitoring sites upstream and downstream of the barrier. A number of factors can contribute to these differences, such as agricultural pumping and discharges, State Water Project and Central Valley Project exports, barrier operations, etc. Also, variation between incoming tidal water and water flowing down the Middle River could be another reason why there is distinct variation in water quality constituents between the upstream and downstream monitoring locations.

Old River Barrier

The Old River at Head barrier was constructed on September 28th, 2005, and removed on November 8th, 2005. This barrier was installed during the fall to aid fish migration in the San Joaquin River. The barrier in the Old River near DMC was constructed on May 31st, 2005, and removed on November 10th, 2005. Monitoring of the Old River was conducted at four sites: 1) Old River at Head (site 10), 2) Tracy Road bridge over Old River (site 6), 3) immediately upstream of the barrier in Old River near DMC (site 5), and 4) immediately downstream of the barrier in Old River near DMC (site 4). Figure 8-4 and Tables 8-5 to 8-8 show the weekly water quality field and lab data for the Old River.

Figure 8-4. Old River - Weekly Water Quality Data

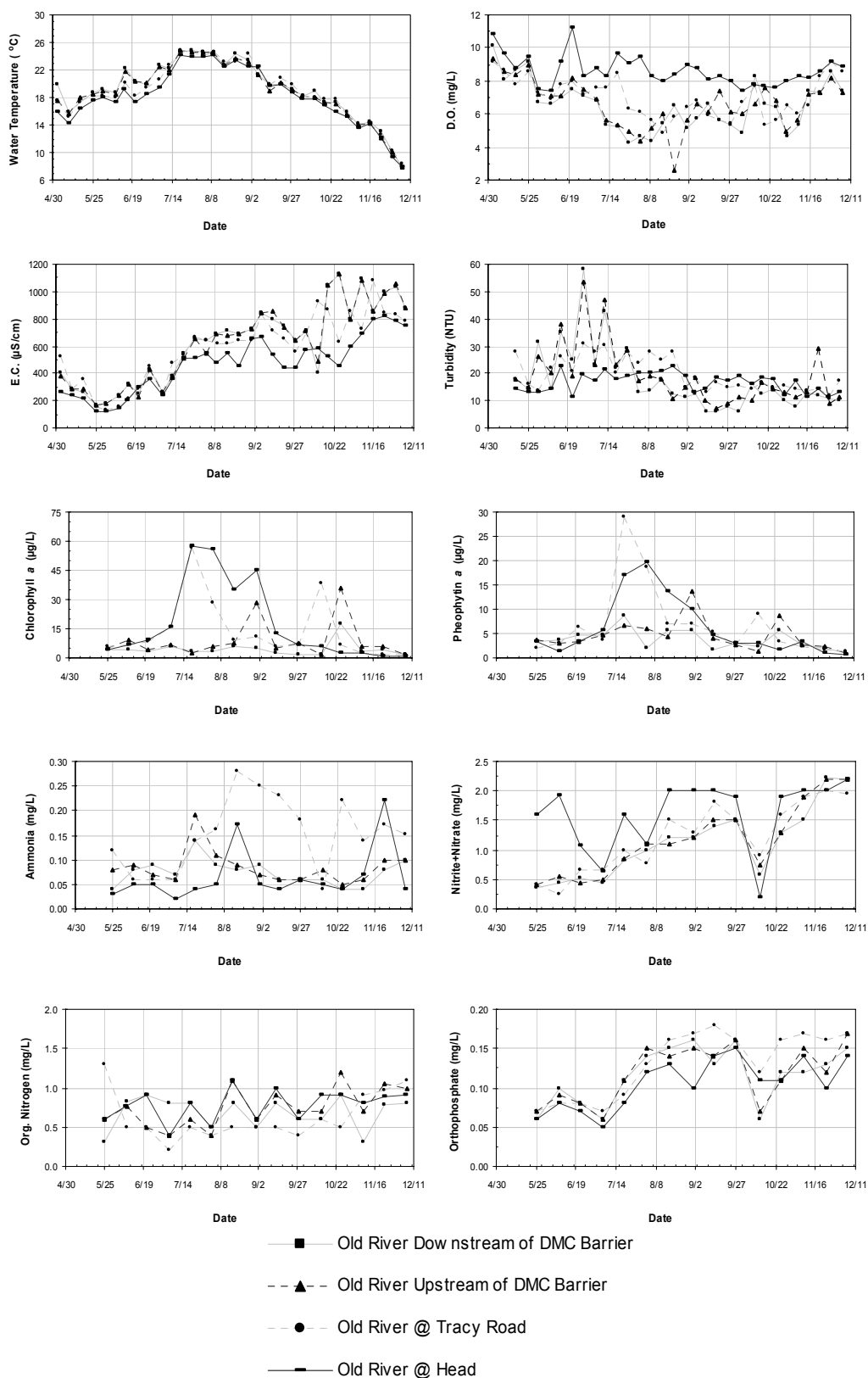


Table 8-5. Old River at DMC - Downstream of Barrier: 2005 Water Quality Data

OLD RIVER @ DMC - DOWNSTREAM OF BARRIER (B9D74871328)
 South Delta Temporary Barriers Project - 2005 Weekly Water Quality Sampling Data

DATE & TIME (mm/dd/yy PST)	FIELD READINGS					BRYTE LAB RESULTS						
	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
5/3/05 8:45	19.8	10.1	401		4.90							
5/10/05 7:58	15.8	8.1	283		6.70							
5/17/05 7:26	17.4	8.7	266	17.9	4.70							
5/25/05 7:05	18.6	9.2	170		7.65	0.04	0.37	0.3	0.06	14.0	4.49	3.25
5/31/05 7:30	19.2	6.7	180	31.3	3.80							
6/8/05 7:52	18.6	6.6	238		5.40	0.08	0.44	0.8	0.10	14.0	4.27	3.58
6/14/05 7:50	22.2	7.0	322	35.2	3.25							
6/21/05 7:42	20.3	7.5	255		5.40	0.09	0.52	0.9	0.08	25.0	3.26	4.59
6/28/05 7:20	20.0	7.1	422	58.2	3.03							
7/6/05 7:30	22.7	6.8	256		5.25	0.07	0.45	0.8	0.06	23.0	6.09	4.79
7/12/05 6:54	22.2	5.3	384	42.7	3.40							
7/19/05 7:45	24.7	5.2	545		4.30	0.14	0.83	0.8	0.11	22	3.58	8.79
7/26/05 7:43	24.8	4.3	657	28.9	2.85							
8/2/05 7:12	24.7	4.6	638		4.10	0.09	1.00	0.5	0.14	13.0	3.10	2.06
8/9/05 6:36	24.4	4.4	692	13.7	3.89							
8/16/05 7:49	22.6	5.4	718		2.98	0.08	1.20	0.8	0.15	18.0	6.14	5.63
8/23/05 8:10	24.4	6.5	693	12.3	5.29							
8/31/05 7:31	23.4	5.1	726		3.00	0.09	1.20	0.5	0.16	11.0	4.97	5.76
9/6/05 6:46	21.4	5.7	842	12.7	4.27							
9/13/05 7:47	19.9	6.6	797		2.50	0.06	1.40	0.8	0.13	6.0	2.51	1.83
9/20/05 7:22	19.9	5.6	745	5.9	3.22							
9/27/05 8:02	19.2	5.3	645		2.30	0.06	1.50	0.6	0.16	8.0	1.55	3.05
10/4/05 7:20	18.3	4.8	709	6.1	3.45							
10/12/05 7:50	18.9	8.3	399		2.10	0.06	0.58	0.6	0.06	16.0	1.92	2.26
10/18/05 7:30	17.3	6.6	1041	12.2	3.42							
10/25/05 8:00	17.2	6.4	1134		2.05	0.04	1.30	0.9	0.12	14.0	17.40	5.54
11/1/05 7:54	15.9	4.6	791	10.1	2.60							
11/8/05 8:37	13.9	5.3	1098		2.35	0.04	1.50	0.3	0.12	8.0	3.26	2.80
11/15/05 8:00	14.5	7.4	852	13.2	2.90							
11/22/05 8:52	13.0	7.3	1001		2.00	0.08	2.22	0.8	0.13	12.0	4.38	1.86
11/29/05 8:50	9.9	8.6	1036	10.4	2.54							
12/6/05 8:31	8.0	7.4	882		1.98	0.10	2.20	0.8	0.15	10.0	1.41	0.84

█ = Old River near DMC barrier in place from 5/31/05 - 11/10/05.

	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Maximum	24.80	10.10	1,134.00	58.20	7.65	0.14	2.22	0.90	0.16	25.00	17.40	8.79
Minimum	8.00	4.30	170.00	5.90	1.98	0.04	0.37	0.30	0.06	6.00	1.41	0.84
Mean	19.16	6.51	619.31	20.72	3.67	0.07	1.11	0.68	0.12	14.27	4.56	3.78
Range	16.80	5.80	964.00	52.30	5.67	0.10	1.85	0.60	0.10	19.00	15.99	7.95
Standard Deviation	4.21	1.49	290.18	15.24	1.40	0.03	0.60	0.20	0.04	5.68	3.84	2.08
Sample Variance	17.70	2.23	84,207.19	232.19	1.97	0.00	0.36	0.04	0.00	32.21	14.76	4.32
Standard Error	3.64	1.36	278.43	11.91	0.79	0.03	0.62	0.21	0.04	4.83	3.94	1.97
Median	19.50	6.60	674.50	13.20	3.33	0.08	1.20	0.80	0.12	14.00	3.58	3.25
Mode	18.60	6.60	-	-	5.40	0.04	1.20	0.80	0.06	14.00	3.26	-
Count	32	32	32	15	32	15	15	15	15	15	15	15
Confidence Interval (95%)*	1.46	0.52	100.54	7.71	0.49	0.01	0.30	0.10	0.02	2.87	1.94	1.05

* Mean (µ) for Temperature = 19.16; 95% Confidence interval is 19.16 ± 1.46 or $17.70 \leq \mu \leq 20.62$. This means the interval between 17.70 and 20.62 has a .95 probability of containing µ.

Table 8-6. Old River at DMC - Upstream of Barrier: 2005 Water Quality Data

OLD RIVER @ DMC - UPSTREAM OF BARRIER (B9D74861325)
 South Delta Temporary Barriers Project - 2005 Weekly Water Quality Sampling Data

DATE & TIME (mm/dd/yy PST)	FIELD READINGS					BRYTE LAB RESULTS						
	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
5/3/05 8:20	17.5	9.4	386		4.25							
5/10/05 7:35	15.6	8.6	281		7.05							
5/17/05 7:04	17.9	8.4	291	17.8	4.90							
5/25/05 6:50	18.4	9.0	170		7.75	0.08	0.41	0.6	0.07	15.0	5.02	3.54
5/31/05 7:05	19.0	7.2	173	26.4	4.30							
6/8/05 7:19	18.5	7.1	236		6.20	0.09	0.55	0.8	0.09	20.0	9.13	2.94
6/14/05 7:20	21.8	7.1	322	38.0	4.00							
6/21/05 7:15	20.4	8.2	228		6.20	0.07	0.43	0.5	0.08	19.0	3.84	3.33
6/28/05 7:00	20.1	7.5	423	53.6	3.65							
7/6/05 7:01	22.4	6.9	258		5.61	0.06	0.49	0.4	0.06	23.0	6.46	4.64
7/12/05 6:43	22.1	5.6	385	46.9	3.65							
7/19/05 7:20	24.9	5.3	515		6.38	0.19	0.86	0.6	0.11	23	2.88	6.61
7/26/05 6:30	24.7	4.9	655	28.3	4.95							
8/2/05 6:48	24.6	4.4	542		5.69	0.11	1.10	0.4	0.15	17.0	5.45	5.99
8/9/05 6:19	24.5	5.1	693	19.1	4.70							
8/16/05 7:15	22.8	6.1	677		5.80	0.09	1.10	1.1	0.14	18.0	7.42	4.35
8/23/05 8:45	23.7	2.6	693	10.9	4.98							
8/31/05 7:02	23.1	5.6	727		5.20	0.07	1.20	0.6	0.15	15.0	28.70	13.80
9/6/05 6:30	21.3	6.6	849	18.3	4.41							
9/13/05 7:17	19.0	6.1	854		5.45	0.06	1.50	0.9	0.14	10.0	4.86	3.96
9/20/05 7:05	20.1	7.4	740	7.4	4.50							
9/27/05 7:50	19.2	6.1	644		5.10	0.06	1.50	0.7	0.16	9.0	7.69	2.81
10/4/05 7:00	18.2	6.0	709	11.1	3.90							
10/12/05 7:16	18.0	6.6	485		4.35	0.08	0.73	0.7	0.07	10.0	1.66	1.44
10/18/05 7:18	17.2	7.6	1050	16.8	3.80							
10/25/05 7:40	17.0	6.8	1129		4.62	0.05	1.30	1.2	0.11	14.0	35.60	8.54
11/1/05 7:35	15.3	4.9	791	12.8	3.75							
11/8/05 8:30	13.9	5.6	1084		4.75	0.06	1.90	0.7	0.15	11.0	6.19	2.70
11/15/05 7:50	14.2	7.2	855	13.3	2.98							
11/22/05 8:25	12.2	7.3	985		1.80	0.10	2.21	1.1	0.12	29.0	6.14	2.46
11/29/05 8:40	10.1	8.2	1053	8.9	2.58							
12/6/05 8:18	7.9	7.3	885		1.90	0.10	2.19	1.0	0.17	11.0	1.30	0.99

= Old River near DMC barrier in place from 5/31/05 - 11/10/05.

	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Maximum	24.90	9.40	1,129.00	53.60	7.75	0.19	2.21	1.20	0.17	29.00	35.60	13.80
Minimum	7.90	2.60	170.00	7.40	1.80	0.05	0.41	0.40	0.06	9.00	1.30	0.99
Mean	18.93	6.64	617.75	21.97	4.66	0.08	1.16	0.75	0.12	16.27	8.82	4.54
Range	17.00	6.80	959.00	46.20	5.95	0.14	1.80	0.80	0.11	20.00	34.30	12.81
Standard Deviation	4.24	1.45	290.81	14.11	1.34	0.03	0.61	0.25	0.04	5.81	9.80	3.23
Sample Variance	17.96	2.10	84,572.84	199.11	1.79	0.00	0.37	0.06	0.00	33.78	96.05	10.46
Standard Error	3.69	1.28	284.41	11.45	0.73	0.04	0.63	0.21	0.04	5.60	10.14	2.09
Median	19.00	6.85	666.00	17.80	4.66	0.08	1.10	0.70	0.12	15.00	6.14	3.54
Mode	19.00	5.60	693.00	-	6.20	0.06	1.10	0.60	0.15	15.00	-	-
Count	32	32	32	15	32	15	15	15	15	15	15	15
Confidence Interval (95%)*	1.47	0.50	100.76	7.14	0.46	0.02	0.31	0.13	0.02	2.94	4.96	1.64

* Mean (µ) for Temperature = 18.93; 95% Confidence interval is 18.93 ± 1.47 or $17.46 \leq \mu \leq 20.40$. This means the interval between 17.46 and 20.40 has a .95 probability of containing µ.

Table 8-7. Old River at Tracy Road: 2005 Water Quality Data

OLD RIVER @ TRACY ROAD (B9D74831269) South Delta Temporary Barriers Project - 2005 Weekly Water Quality Sampling Data												
DATE & TIME (mm/dd/yy PST)	FIELD READINGS					BRYTE LAB RESULTS						
	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
5/3/05 8:40	17.6	9.2	523		5.15							
5/10/05 7:40	15.2	8.7	281		7.31							
5/17/05 6:40	17.5	7.8	356	27.8	5.68							
5/25/05 7:43	18.2	8.6	153			0.12	0.40	1.3	0.07	16	5.61	2.13
5/31/05 7:20	18.3	7.3	130	13.6	5.12							
6/8/05 7:55	18.0	6.9	153		6.52	0.06	0.25	0.5	0.08	22.0	6.68	3.16
6/14/05 7:42	20.2	7.8	214	26.1	4.12							
6/21/05 8:02	18.3	8.0	290		6.10	0.06	0.65	0.5	0.08	21.0	8.22	6.35
6/28/05 7:27	19.5	7.2	456	30.6	3.68							
7/6/05 7:45	20.5	7.6	256		5.94	0.06	0.66	0.2	0.07	28.0	15.60	3.64
7/12/05 7:39	22.7	7.6	470	30.4	3.66							
7/19/05 7:44	24.8	8.5	540		6.38	0.14	1.00	0.5	0.09	20	56.80	29.00
7/26/05 7:03	24.7	6.3	668	28.2	4.98							
8/2/05 7:45	24.1	6.1	643		5.62	0.16	0.76	0.4	0.13	24.0	28.60	18.70
8/9/05 7:18	24.5	5.6	617	28.2	4.80							
8/16/05 7:23	23.1	4.8	619		5.81	0.28	1.50	0.5	0.16	25.0	9.35	6.95
8/23/05 8:00	23.1	5.8	641	27.8	4.86							
8/31/05 9:22	24.4	6.4	647		4.71	0.25	1.30	0.5	0.17	15.0	11.20	6.88
9/6/05 7:45	22.3	6.8	833	18.4	4.54							
9/13/05 7:50	19.8	5.9	711		5.40	0.23	1.80	0.5	0.18	13	5.55	5.36
9/20/05 7:45	20.8	5.6	654	16.8	4.64							
9/27/05 8:16	19.8	5.4	557		5.97	0.18	1.50	0.4	0.16	15.0	6.46	2.70
10/4/05 7:46	18.3	6.7	697	15.4	3.90							
10/12/05 7:05	18.0	7.7	932		4.49	0.04	0.91	0.6	0.12	14.0	38.70	9.04
10/18/05 7:00	17.8	5.3	867	16.9	3.84							
10/25/05 8:00	17.7	5.6	629		4.68	0.22	1.60	0.5	0.16	15.0	6.84	3.48
11/1/05 8:30	15.5	6.5	857	15.4	3.79							
11/8/05 8:19	14.3	6.0	721		4.68	0.14	1.90	0.9	0.17	14.0	2.35	2.29
11/15/05 8:50	14.3	6.5	1080	13.9	3.15							
11/22/05 8:35	12.5	8.3	841		2.10	0.17	2.00	1.0	0.16	14.0	2.02	1.68
11/29/05 8:50	10.2	9.2	837	11.9	2.60							
12/6/05 8:37	8.3	8.6	784			0.15	1.96	1.1	0.17	17.0	1.58	1.50

█ = Old River near DMC barrier in place from 5/31/05 - 11/10/05.

	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Maximum	24.80	9.20	1,080.00	30.60	7.31	0.28	2.00	1.30	0.18	28.00	56.80	29.00
Minimum	8.30	4.80	130.00	11.90	2.10	0.04	0.25	0.20	0.07	13.00	1.58	1.50
Mean	18.88	7.01	583.03	21.43	4.81	0.15	1.21	0.62	0.13	18.20	13.70	6.86
Range	16.50	4.40	950.00	18.70	5.21	0.24	1.75	1.10	0.11	15.00	55.22	27.50
Standard Deviation	4.15	1.24	248.64	7.03	1.18	0.07	0.59	0.30	0.04	4.77	15.71	7.51
Sample Variance	17.23	1.53	61,824.03	49.42	1.38	0.01	0.35	0.09	0.00	22.74	246.87	56.37
Standard Error	3.82	1.12	241.66	6.52	0.78	0.08	0.48	0.30	0.04	4.15	15.91	3.38
Median	18.30	6.85	635.00	18.40	4.76	0.15	1.30	0.50	0.16	16.00	6.84	3.64
Mode	18.30	5.60	153.00	27.80	4.68	0.06	1.50	0.50	0.16	15.00	-	-
Count	32	32	32	15	30	15	15	15	15	15	15	15
Confidence Interval (95%)*	1.44	0.43	86.15	3.56	0.42	0.04	0.30	0.15	0.02	2.41	7.95	3.80

* Mean (µ) for Temperature = 18.88; 95% Confidence interval is 18.88 ± 1.44 or $17.44 \leq \mu \leq 20.32$. This means the interval between 17.44 and 20.32 has a .95 probability of containing µ.

Table 8-8. Old River at Head: 2005 Water Quality Data

OLD RIVER @ HEAD (B9D74851200)
South Delta Temporary Barriers Project - 2005 Weekly Water Quality Sampling Data

DATE	FIELD READINGS					BRYTE LAB RESULTS						
	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
5/3/05 6:53	15.9	10.8	256		8.07							
5/10/05 5:47	14.2	9.6	233		8.67							
5/17/05 5:33	16.3	8.8	219	14.5	8.61							
5/25/05 5:40	17.5	9.5	123		10.68	0.03	1.60	0.6	0.06	13	4.52	3.26
5/31/05 5:35	17.9	7.5	119	12.9	11.30							
6/8/05 5:40	17.4	7.4	145		11.20	0.05	1.92	0.8	0.08	14.0	7.00	1.45
6/14/05 5:40	19.1	9.2	204	22.6	8.69							
6/21/05 5:30	17.3	11.2	295		8.44	0.05	1.06	0.9	0.07	11.0	8.97	3.25
6/28/05 5:30	18.5	8.3	357	19.8	6.53							
7/6/05 5:31	19.4	8.8	238		7.30	0.02	0.64	0.4	0.05	17.0	15.90	5.51
7/12/05 5:37	21.3	8.3	358	21.2	5.84							
7/19/05 6:06	24.1	9.6	513		7.67	0.04	1.60	0.8	0.08	18.0	57.90	16.90
7/26/05 5:20	23.9	9.1	512	19.2	5.87							
8/2/05 5:15	24.0	9.5	544		6.40	0.05	1.10	0.5	0.12	20.0	56.10	19.60
8/9/05 5:00	24.2	8.3	479	20.2	4.99							
8/16/05 5:49	22.4	8.0	545		6.24	0.17	2.00	1.1	0.13	21.0	34.80	13.80
8/23/05 10:30	23.3	8.4	446	22.7	5.59							
8/31/05 5:15	22.4	9.0	654		5.70	0.05	2.00	0.6	0.10	19.0	45.30	9.95
9/6/05 5:16	22.4	8.8	660	13.3	4.88							
9/13/05 5:25	19.6	8.1	538		5.85	0.04	2.00	1.0	0.14	14.0	12.70	4.78
9/20/05 5:45	19.9	8.3	442	18.7	4.99							
9/27/05 6:10	18.7	8.0	441		5.49	0.06	1.90	0.6	0.15	17.0	6.46	2.85
10/4/05 5:18	17.7	7.4	565	19.2	4.08							
10/12/05 5:30	17.8	7.8	587		4.64	0.05	0.20	0.9	0.11	16.0	6.09	3.07
10/18/05 5:42	16.9	7.7	519	18.2	3.92							
10/25/05 6:00	16.0	7.6	453		4.94	0.04	1.90	0.9	0.11	18.0	2.40	1.56
11/1/05 6:17	15.1	8.0	598	12.1	3.90							
11/8/05 12:00	13.6	8.3	685		4.97	0.07	2.00	0.8	0.14	17.0	2.72	3.41
11/15/05 6:25	14.2	8.2	796	11.3	4.19							
11/22/05 6:30	12.2	8.6	820		2.94	0.22	2.01	0.9	0.10	14.0	1.01	1.10
11/29/05 7:10	9.3	9.2	790	11.0	3.75							
12/6/05 6:50	7.8	8.9	748		2.91	0.04	2.19	0.9	0.14	13.0	0.57	0.59

█ = Old River Near DMC barrier in place from 5/31/05 - 11/10/05.

Note: Old River @ Head Barrier in place from 9/28/05 - 11/8/05.

	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Maximum	24.20	11.24	820.00	22.70	11.30	0.22	2.19	1.10	0.15	21.00	57.90	19.60
Minimum	7.80	7.40	119.00	11.00	2.91	0.02	0.20	0.40	0.05	11.00	0.57	0.59
Mean	18.13	8.63	465.06	17.13	6.23	0.07	1.61	0.78	0.11	16.13	17.50	6.07
Range	16.40	3.84	701.00	11.70	8.39	0.20	1.99	0.70	0.10	10.00	57.33	19.01
Standard Deviation	4.16	0.90	203.36	4.16	2.27	0.05	0.59	0.20	0.03	2.88	20.40	6.07
Sample Variance	17.32	0.81	41,354.45	17.33	5.14	0.00	0.35	0.04	0.00	8.27	416.32	36.85
Standard Error	3.90	0.92	204.03	3.88	2.25	0.05	0.58	0.19	0.03	2.87	15.88	1.70
Median	17.85	8.35	495.50	18.70	5.77	0.05	1.90	0.80	0.11	17.00	7.00	3.26
Mode	22.40	8.30	-	19.20	4.99	0.05	2.00	0.90	0.14	14.00	-	-
Count	32	32	32	15	32	15	15	15	15	15	15	15
Confidence Interval (95%)*	1.44	0.31	70.46	2.11	0.79	0.03	0.30	0.10	0.02	1.46	10.33	3.07

* Mean (μ) for Temperature = 18.13; 95% Confidence interval is 18.13 ± 1.44 or $16.69 \leq \mu \leq 19.57$. This means the interval between 16.69 and 19.57 has a .95 probability of containing μ .

Water temperature data recorded for the Old River followed seasonal patterns. Generally, temperatures at all four sites increased steadily from spring into early summer, remained elevated throughout the summer, and decreased in fall. Temperatures at the four monitoring sites tracked well and there were no notable temperature differences. Mean temperatures during the monitoring period ranged from 18.13 °C at the Old River at Head site to 19.16 °C at the Downstream of DMC Barrier site. The highest recorded temperature was 24.9 °C on July 19th at the Upstream of DMC Barrier site and the lowest was 7.8 °C on December 6th at the Old River at Head site.

Dissolved oxygen levels were lowest in the summer and early fall, in part due to warm water temperatures and low San Joaquin River flows at all the monitoring sites except Old River at Head. During this time period nine field readings collected at the DMC sites, in the immediate vicinity of the barrier, were less than 5 mg/L. The minimum dissolved oxygen value recorded was 2.60 mg/L on August 23rd in the Old River Upstream of the DMC barrier. Mean DO concentrations immediately upstream and downstream of the DMC Barrier were 6.64 mg/L and 6.51 mg/L, respectively, showing little variation. Old River at Tracy Road tended to have higher DO concentrations than at the sites near the barrier and had an average DO concentration of 7.01 mg/L. One field reading collected at Tracy Road was less than 5 mg/L. Old River at Head had consistently higher DO concentrations in comparison to the other three sites on Old River averaging 8.63 mg/L. Readings at the Head site were elevated throughout the monitoring period with no observable pattern. The high summer DO readings at Old River at Head were probably a result of the photosynthetic activity of phytoplankton. A maximum DO reading of 11.2 mg/L was recorded on June 21st, and a minimum value of 7.40 mg/L was recorded on October 4th, at the Old River at Head site.

From May until August specific conductance at all four monitoring locations tracked closely. From August through December specific electrical conductivity readings tended to be lower at the Old River at Head site. Immediately upstream and downstream of the DMC Barrier there were minimal differences in specific conductance with means of 618 and 619 µS/cm, respectively. Values were less upstream at the Tracy Road site averaging 583 µS/cm. Finally, specific electrical conductivity values at Old River at Head, the furthest upstream site, were lower than the other sites averaging 465 µS/cm. The lowest recorded specific electrical conductivity reading for the Old River was 119 µS/cm on May 31st at the Old River at Head site and the highest was 1,134 µS/cm on October 25th at the Downstream of DMC Barrier site.

Turbidity values in the Old River were highest from late spring to mid summer. Tracy Road had the highest turbidity readings during this time period and had a mean of 19.8 NTU. In the immediate vicinity of the barrier turbidity readings averaged 19.1 NTU at the upstream site and 17.5 NTU at the downstream site. Turbidity at the Head site averaged 16.6 NTU. The lowest recorded turbidity value was 5.9 NTU on September 20th, and the highest was 58.2 NTU on June 28th, both at the Downstream of DMC Barrier Site.

Chlorophyll *a* concentrations were highest at the Old River at Head and Tracy Road sites. Values at Head began increasing in early June, remained high throughout the summer and began decreasing in early fall. The mean chlorophyll *a* concentration at the Head site was 17.5 µg/L. Elevated chlorophyll *a* concentrations were also observed at Tracy Road during the summer. The mean chlorophyll *a* concentration at Tracy Road was 13.7 µg/L. Immediately upstream and downstream of the DMC barrier chlorophyll *a* concentrations were comparatively low, averaging 8.82 µg/L and 4.56 µg/L, respectively. A maximum chlorophyll *a* value of 57.9 µg/L was recorded on July 19th and a minimum of 0.57 µg/L was recorded on December 6th, both at the Old River at Head site. Trends in pheophytin *a* concentrations mimicked those seen in the chlorophyll *a* concentrations at all four Old River sites.

Ammonia concentrations tracked well between all four sampling locations during the late spring and early summer after which Tracy Road tended to have higher concentrations for the remainder of the monitoring period. Values at Tracy Road ranged from 0.04 to 0.28 mg/L with a mean of 0.15 mg/L, while values further upstream at the Head site ranged from 0.02 to 0.22 mg/L with a mean of 0.07 mg/L. The maximum measured ammonia concentration was 0.28 mg/L on August 16th at Tracy Road. Values immediately upstream and downstream of the DMC barrier showed little variation averaging 0.08 mg/L and 0.07 mg/L, respectively.

Nitrite-nitrate levels tended to increase at all four monitoring sites from late spring through the fall, except on October 12th when nitrite-nitrate values decreased at all four stations. Old River at Head had the highest nitrite-nitrate concentrations with an average of 1.61 mg/L. Old River at Head reached a maximum value of 2.19 mg/L on December 6th. Old River at Tracy Road had lower concentrations than Head with an average of 1.21 mg/L. Generally, when compared to the other two monitoring locations, the DMC sites had the lowest nitrite-nitrate concentrations throughout the monitoring period with mean values of 1.16 mg/L and 1.11 mg/L. A minimum of 0.20 mg/L was recorded on October 12th at the Old River at Head site.

Organic nitrogen concentrations showed no distinct patterns during the monitoring period. The minimum organic nitrogen concentration in the Old River was 0.20 mg/L reported on July 6th and the maximum was 1.30 mg/L reported on May 25th, both at Tracy Road. Old River at Tracy Road had the lowest organic nitrogen concentrations during the sampling period with a mean of 0.62 mg/L, while Old River at Head had the highest concentrations with a mean of 0.78 mg/L. Mean organic nitrogen concentrations at the Upstream and Downstream of DMC barrier sites were 0.75 mg/L and 0.68 mg/L, respectively.

Orthophosphate values at all sites ranged from 0.05 to 0.18 mg/L. Values were similar at all four locations throughout the monitoring period and were higher during the summer. The highest mean was 0.13 mg/L at the Tracy Road site, and the lowest was 0.11 mg/L at the Head site.

Overall, there were not any notable differences in the water quality constituents at the sites immediately upstream and downstream of the DMC barrier; however, water quality constituents did vary upstream at the Tracy Road and Head sites. Ammonia concentrations tended to be higher at the Tracy Road site in comparison to the downstream sites near the DMC barrier and the upstream site, Old River at Head. In comparison to the other three Old River monitoring sites, the Old River at Head site had higher dissolved oxygen and nitrite-nitrate concentrations and lower turbidity and specific conductance values. Both the Old River at Head and Tracy Road sites had greater chlorophyll *a* / pheophytin *a* concentrations relative to the sites just upstream and downstream of the DMC barrier.

Grant Line Canal Barrier

The Grant Line Canal barrier was constructed on July 14th, 2005 and removed on November 15th, 2005. Monitoring of Grant Line Canal consisted of three sites: 1) in Doughty Cut upstream of Grant Line Canal (site 7), 2) immediately upstream of the barrier (site 8), and 3) Tracy Road bridge over Grant Line Canal (site 9). Figure 8-5 and Tables 8-9 to 8-11 show the weekly water quality field and lab data for Grant Line Canal.

There were no notable water temperature differences between the GLC sites. A maximum temperature of 24.8 °C was recorded at Tracy Road on July 26th and a minimum temperature of 8.0 °C was recorded at Doughty Cut on December 6th. Mean water temperatures ranged from 18.53 to 18.75 °C at the three monitoring stations. Similar to the Middle River and Old River, water temperatures in GLC tended to follow seasonal patterns.

Figure 8-5. Grant Line Canal – 2005 Weekly Water Quality Data

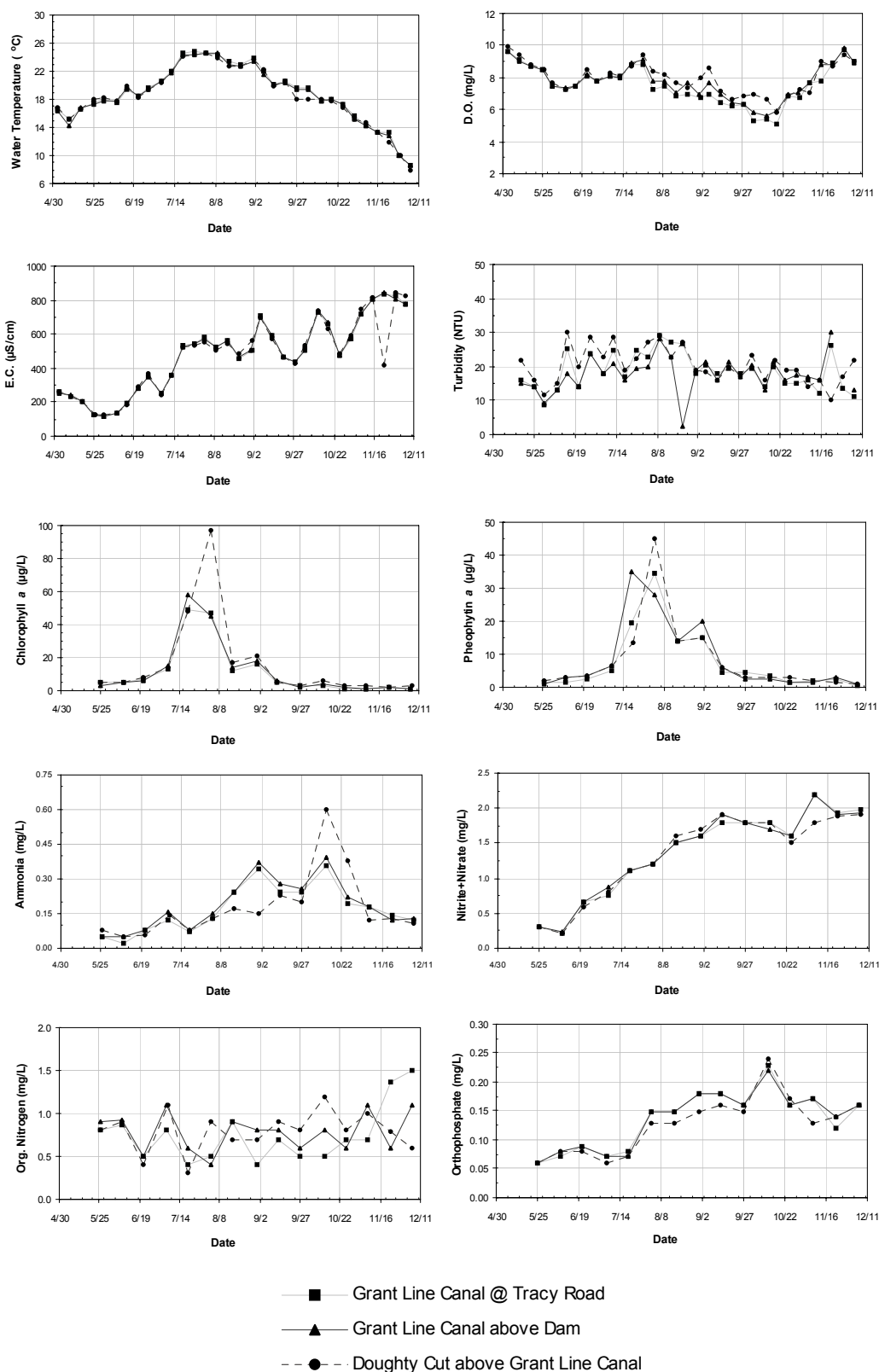


Table 8-9. Grant Line Canal at Tracy Road: 2005 Water Quality Data

GRANT LINE CANAL @ TRACY ROAD (B9D74921269)
South Delta Temporary Barriers Project - 2005 Weekly Water Quality Sampling Data

DATE & TIME (mm/dd/yy PST)	FIELD READINGS					BRYTE LAB RESULTS						
	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
5/3/05 7:32	16.5	9.6	259		4.25							
5/10/05 6:40	15.1	9.1	237		7.15							
5/17/05 6:00	16.6	8.7	203	16.1	5.91							
5/25/05 6:15	17.6	8.5	128		7.90	0.05	0.30	0.8	0.06	14.0	4.81	1.47
5/31/05 6:00	18.0	7.5	119	8.7	5.31							
6/8/05 6:40	17.5	7.3	132		7.02	0.02	0.22	0.9	0.07	13.0	5.39	1.48
6/14/05 6:50	19.5	7.5	194	25.1	3.38							
6/21/05 6:50	18.5	8.1	279		6.95	0.08	0.66	0.5	0.09	14.0	7.48	2.65
6/28/05 6:15	19.6	7.8	353	23.9	4.05							
7/6/05 6:55	20.5	8.1	250		6.68	0.12	0.75	0.8	0.07	18.0	13.20	4.98
7/12/05 6:03	21.9	8.1	357	24.9	3.96							
7/19/05 6:25	24.6	8.8	532		5.46	0.07	1.10	0.4	0.08	17.0	49.10	19.50
7/26/05 6:08	24.8	8.8	546	24.6	2.58							
8/2/05 6:43	24.5	7.3	578		4.65	0.13	1.20	0.5	0.15	23.0	46.70	34.40
8/9/05 6:28	24.4	7.5	521	29.0	3.65							
8/16/05 6:05	23.4	6.8	560		4.06	0.24	1.50	0.9	0.15	27.0	11.70	14.10
8/23/05 7:00	22.9	7.0	456	26.5	4.59							
8/31/05 8:21	23.9	6.7	505		3.70	0.34	1.60	0.4	0.18	18.0	15.80	15.10
9/6/05 7:06	22.0	7.0	706	20.3	4.80							
9/13/05 6:56	20.2	6.4	588		3.52	0.24	1.80	0.7	0.18	18.0	4.97	4.57
9/20/05 7:44	20.5	6.2	463	19.5	3.15							
9/27/05 7:08	19.6	6.3	436		2.80	0.24	1.80	0.5	0.16	18.0	2.51	4.26
10/4/05 6:38	19.6	5.3	510	19.6	3.50							
10/12/05 6:44	17.7	5.4	731		2.30	0.36	1.80	0.5	0.23	14.0	2.94	3.49
10/18/05 5:55	18.0	5.1	664	20.1								
10/25/05 7:01	17.3	6.8	474		2.50	0.19	1.60	0.7	0.16	15	1.42	1.37
11/1/05 6:29	15.7	6.7	568	15.2	2.80							
11/8/05 7:01	14.2	7.7	717		2.00	0.18	2.20	0.7	0.17	16.0	1.32	2.23
11/15/05 7:48	13.4	7.8	805	12.3	3.90							
11/22/05 9:31	13.2	8.9	839		2.30	0.14	1.94	1.4	0.12	26.0	2.14	2.46
11/29/05 7:45	10.1	9.7	827	13.6	2.80							
12/6/05 7:32	8.6	9.0	776			0.12	1.97	1.5	0.16	11.0	0.76	0.71

 = Grant Line Canal barrier in place from 7/14/05 - 11/15/05.


	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Maximum	24.80	9.70	839.00	29.00	7.90	0.36	2.20	1.50	0.23	27.00	49.10	34.40
Minimum	8.60	5.10	119.00	8.70	2.00	0.02	0.22	0.40	0.06	11.00	0.76	0.71
Mean	18.75	7.55	478.53	19.96	4.25	0.17	1.36	0.74	0.14	17.47	11.35	7.52
Range	16.20	4.60	720.00	20.30	5.90	0.34	1.98	1.10	0.17	16.00	48.34	33.69
Standard Deviation	4.14	1.21	217.12	5.83	1.63	0.10	0.63	0.33	0.05	4.64	15.53	9.42
Sample Variance	17.10	1.46	47,141.35	34.02	2.67	0.01	0.39	0.11	0.00	21.55	241.22	88.82
Standard Error	3.89	1.16	218.42	6.02	1.00	0.07	0.49	0.33	0.05	4.80	15.40	4.28
Median	19.00	7.50	507.50	20.10	3.93	0.14	1.60	0.70	0.15	17.00	4.97	3.49
Mode	19.60	7.50	-	-	2.80	0.24	1.80	0.50	0.16	18.00	-	-
Count	32	32	32	15	30	15	15	15	15	15	15	15
Confidence Interval (95%)*	1.43	0.42	75.23	2.95	0.58	0.05	0.32	0.16	0.03	2.35	7.86	4.77

* Mean (µ) for Temperature = 18.75; 95% Confidence interval is 18.75 ± 1.43 or $17.32 \leq \mu \leq 20.18$. This means the interval between 17.32 and 20.18 has a .95 probability of containing µ.

Table 8-10. Grant Line Canal Above Barrier: 2005 Water Quality Data

GRANT LINE CANAL ABOVE BARRIER (B9D74921510)
South Delta Temporary Barriers Project - 2005 Weekly Water Quality Sampling Data

DATE & TIME (mm/dd/yy PST)	FIELD READINGS					BRYTE LAB RESULTS						
	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
5/3/05 7:05	16.3	9.6	257		5.45							
5/10/05 6:22	14.2	9.0	245		7.10							
5/17/05 5:50	16.8	8.7	204	15.1	5.59							
5/25/05 6:02	17.4	8.5	129		7.85	0.05	0.31	0.9	0.06	14.0	3.10	1.20
5/31/05 5:46	17.8	7.5	119	9.4	5.33							
6/8/05 6:23	17.7	7.4	132		7.05	0.05	0.23	0.9	0.08	13.0	5.23	3.03
6/14/05 6:36	19.6	7.5	193	18.2	4.40							
6/21/05 6:30	18.4	8.2	282		7.00	0.08	0.65	0.5	0.09	14.0	6.41	3.61
6/28/05 6:03	19.4	7.8	354	23.9	4.08							
7/6/05 6:47	20.5	8.1	250		6.68	0.16	0.87	1.1	0.07	18.0	15.10	6.61
7/12/05 5:51	21.7	8.0	359	21.1	3.98							
7/19/05 6:10	24.4	8.9	526		5.50	0.08	1.10	0.6	0.07	16.0	58.30	35.00
7/26/05 5:53	24.4	9.1	545	19.3	2.60							
8/2/05 6:30	24.7	7.8	574		4.70	0.15	1.20	0.4	0.15	20.0	45.10	28.10
8/9/05 6:18	24.6	7.8	521	28.0	3.85							
8/16/05 5:45	22.9	7.1	560		4.08	0.24	1.50	1	0.15	23.0	13.70	14.10
8/23/05 6:40	22.6	7.7	462	2.4	4.58							
8/31/05 8:05	23.4	6.9	505		2.90	0.37	1.60	0.8	0.18	19.0	17.80	19.80
9/6/05 6:55	21.6	7.7	703	21.6	4.84							
9/13/05 6:41	20.1	6.9	591		4.50	0.28	1.90	0.8	0.18	16.0	6.30	5.88
9/20/05 6:31	20.3	6.4	464	21.2	2.98							
9/27/05 6:53	19.4	6.3	434		2.74	0.26	1.80	0.6	0.16	17.0	2.46	2.70
10/4/05 6:30	19.5	5.8	508	20.4	3.28							
10/12/05 6:38	17.8	5.6	734		2.30	0.39	1.70	0.8	0.22	13.0	4.27	2.61
10/18/05 5:46	17.9	5.9	674	21.2								
10/25/05 6:54	17.4	6.9	472		2.50	0.22	1.60	0.6	0.16	16.0	2.30	1.74
11/1/05 6:17	15.2	7.1	569	17.7	2.77							
11/8/05 6:40	14.2	7.7	721		2.00	0.18	2.20	1.1	0.17	17.0	1.11	1.72
11/15/05 7:45	13.3	8.8	802	15.9	3.90							
11/22/05 9:50	12.9	8.8	846		2.30	0.12	1.92	0.6	0.14	30.0	1.71	2.89
11/29/05 7:58	10.0	9.8	805		2.80							
12/6/05 7:16	8.5	8.9	775			0.13	1.94	1.1	0.16	13.0	0.87	0.79

 = Grant Line Canal barrier in place from 7/14/05 - 11/15/05.

	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Maximum	24.70	9.80	846.00	28.00	7.85	0.39	2.20	1.10	0.22	30.00	58.30	35.00
Minimum	8.50	5.60	119.00	2.40	2.00	0.05	0.23	0.40	0.06	13.00	0.87	0.79
Mean	18.59	7.76	478.59	18.24	4.32	0.18	1.37	0.78	0.14	17.27	12.25	8.65
Range	16.20	4.20	727.00	25.60	5.85	0.34	1.97	0.70	0.16	17.00	57.43	34.21
Standard Deviation	4.13	1.09	216.17	6.29	1.65	0.11	0.62	0.23	0.05	4.53	17.04	10.74
Sample Variance	17.08	1.19	46,729.15	39.60	2.72	0.01	0.38	0.05	0.00	20.50	290.46	115.26
Standard Error	3.89	1.05	219.43	6.32	0.90	0.08	0.51	0.23	0.05	4.67	17.60	2.91
Median	18.90	7.75	506.50	19.85	4.08	0.16	1.60	0.80	0.15	16.00	5.23	3.03
Mode	14.20	7.80	-	21.20	4.08	0.05	1.60	0.60	0.16	13.00	-	-
Count	32	32	32	14	30	15	15	15	15	15	15	15
Confidence Interval (95%)*	1.43	0.38	74.90	3.30	0.59	0.05	0.31	0.11	0.02	2.29	8.62	5.43

* Mean (µ) for Temperature = 18.59; 95% Confidence interval is 18.59 ± 1.43 or $17.16 \leq \mu \leq 20.02$. This means the interval between 17.16 and 20.02 has a .95 probability of containing µ.

Table 8-11. Doughty Cut Above Grant Line Canal: 2005 Water Quality Data

DOUGHTY CUT ABOVE GRANT LINE CANAL (B9D74911256)
South Delta Temporary Barriers Project - 2005 Weekly Water Quality Sampling Data

DATE & TIME (mm/dd/yy PST)	FIELD READINGS					BRYTE LAB RESULTS						
	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
5/3/05 8:15	16.9	9.9	258		5.19							
5/10/05 7:03	15.2	9.4	232		7.31							
5/17/05 6:25	16.7	8.8	208	21.7	5.93							
5/25/05 7:00	18.1	8.5	128		8.13	0.08	0.30	0.8	0.06	16.0	5.07	2.03
5/31/05 6:50	18.3	7.7	127	11.5	5.68							
6/8/05 7:17	17.8	7.3	134		7.30	0.05	0.22	0.9	0.08	15.0	5.13	3.06
6/14/05 7:17	19.9	7.5	185	30.0	4.68							
6/21/05 7:30	18.2	8.5	287		6.80	0.06	0.60	0.4	0.08	20.0	8.12	3.32
6/28/05 6:51	19.5	7.8	369	28.5	4.19							
7/6/05 7:23	20.3	8.3	246		6.00	0.14	0.80	1.1	0.06	23.0	14.50	6.56
7/12/05 6:17	21.9	8.1	359	28.7	3.70							
7/19/05 7:09	24.2	8.7	520		6.37	0.08	1.10	0.3	0.07	19.0	48.50	13.60
7/26/05 6:40	24.4	9.4	534	22.4	4.90							
8/2/05 7:30	24.5	8.4	550		5.62	0.13	1.20	0.9	0.13	27.0	97.20	45.20
8/9/05 6:59	23.9	8.2	503	29.0	4.85							
8/16/05 6:45	22.7	7.7	545		5.83	0.17	1.60	0.7	0.13	23.0	16.70	14.20
8/23/05 7:30	22.7	7.4	483	27.0	4.95							
8/31/05 8:54	23.7	8.0	564		4.92	0.15	1.70	0.7	0.15	19.0	20.80	14.80
9/6/05 7:25	22.3	8.6	703	18.3	4.71							
9/13/05 7:30	19.9	7.2	575		5.40	0.23	1.90	0.9	0.16	16.0	4.54	6.15
9/20/05 7:16	20.5	6.6	469	19.8	4.70							
9/27/05 7:43	18.0	6.8	432		5.10	0.20	1.80	0.8	0.15	17.0	3.15	2.94
10/4/05 7:20	17.9	7.0	533	23.5	3.90							
10/12/05 7:35	18.1	6.6	734		4.36	0.60	1.80	1.2	0.24	16.0	6.41	3.16
10/18/05 6:28	17.7	5.8	627	21.8	3.81							
10/25/05 7:43	16.8	6.8	489		4.69	0.38	1.50	0.8	0.17	19.0	2.83	2.81
11/1/05 6:58	15.2	7.3	592	19.0	4.22							
11/8/05 7:44	14.7	7.1	743		4.66	0.12	1.80	1.0	0.13	14.0	2.67	1.78
11/15/05 8:30	13.2	9.0	811	16.0	3.38							
11/22/05 9:08	11.9	8.7	419		2.10	0.13	1.88	0.8	0.14	10.0	1.83	1.53
11/29/05 8:30	10.0	9.4	845	17.0	2.60							
12/6/05 8:05	8.0	9.0	823		1.90	0.11	1.91	0.6	0.16	22.0	2.57	0.98

= Grant Line Canal barrier in place from 7/14/05 - 11/15/05.

	TEMP. (°C)	D.O. (mg/L)	E.C. (µS/cm)	TURB. (NTU)	GAGE HEIGHT (ft)	NH ₃ -N (mg/L)	NO ₂ +NO ₃ -N (mg/L)	ORG.-N (mg/L)	PO ₄ (mg/L)	TURB. (NTU)	CHL.-A (µg/L)	PHEO.-A (µg/L)
Maximum	24.50	9.90	845.00	30.00	8.13	0.60	1.91	1.20	0.24	27.00	97.20	45.20
Minimum	8.00	5.80	127.00	11.50	1.90	0.05	0.22	0.30	0.06	10.00	1.83	0.98
Mean	18.53	7.98	469.59	22.28	4.93	0.18	1.34	0.79	0.13	18.40	16.00	8.14
Range	16.50	4.10	718.00	18.50	6.23	0.55	1.69	0.90	0.18	17.00	95.37	44.22
Standard Deviation	4.15	0.99	210.44	5.51	1.41	0.14	0.60	0.24	0.05	4.26	25.49	11.32
Sample Variance	17.23	0.97	44,284.70	30.38	2.00	0.02	0.36	0.06	0.00	18.11	649.71	128.06
Standard Error	3.80	0.99	213.27	5.47	0.90	0.14	0.55	0.24	0.05	4.38	20.53	3.38
Median	18.15	8.05	496.00	21.80	4.88	0.13	1.60	0.80	0.13	19.00	5.13	3.16
Mode	15.20	9.40	-	-	-	0.08	1.80	0.80	0.13	16.00	-	-
Count	32	32	32	15	32	15	15	15	15	15	15	15
Confidence Interval (95%)*	1.44	0.34	72.91	2.79	0.49	0.07	0.30	0.12	0.03	2.15	12.90	5.73

* Mean (µ) for Temperature = 18.53; 95% Confidence interval is 18.53 ± 1.44 or $17.09 \leq \mu \leq 19.97$. This means the interval between 17.09 and 19.97 has a .95 probability of containing µ.

Dissolved oxygen levels tended to be lower in the late summer and early fall in Grant Line Canal. DO concentrations at Doughty Cut were slightly higher than at GLC Above Barrier and Tracy Road averaging 7.98 mg/L and reaching a maximum of 9.90 mg/L on May 3rd. DO at GLC Above Barrier was slightly lower than at Doughty Cut with an average of 7.76 mg/L and a maximum of 9.80 mg/L was recorded on November 29th. GLC at Tracy Road had slightly lower

DO concentrations than the other two sites with an average of 7.55 mg/L. The maximum recorded DO at Tracy Road was 9.70 mg/L on November 29th. The minimum DO value for GLC was 5.10 mg/L recorded on October 18th at Tracy Road.

Generally, specific conductance values increased throughout the monitoring period. Data at the three GLC stations, on average, showed little variation, with mean values ranging from 470 $\mu\text{S}/\text{cm}$ at Doughty Cut to 479 $\mu\text{S}/\text{cm}$ at GLC Above Barrier. Overall, values ranged from a low of 119 $\mu\text{S}/\text{cm}$ on May 31st at both the Tracy Road and the GLC Above Barrier sites to a high of 846 $\mu\text{S}/\text{cm}$ on November 22nd at the GLC Above Barrier site.

Turbidity readings in GLC were highest from late May through early August and then decreased gradually until late fall. Turbidity values varied slightly between sites with values for all three monitoring stations with mean values ranging from 17.8 NTU at GLC Above Barrier to 20.3 NTU at Doughty Cut. The maximum turbidity reading in GLC was 30.0 NTU on June 14th and November 22nd at Doughty Cut and GLC Above Barrier, respectively and a minimum reading of 2.4 NTU on August 23rd at GLC Above Barrier.

Chlorophyll *a* concentrations followed the same general trend at the three GLC sites, except on August 2nd, when a maximum value of 97.2 $\mu\text{g}/\text{L}$ was recorded at Doughty Cut. Algal biomass was highest at the three GLC stations from late June through early August. Mean chlorophyll *a* concentrations ranged from a high of 16.0 $\mu\text{g}/\text{L}$ at Doughty Cut to a low of 11.4 $\mu\text{g}/\text{L}$ at Tracy Road. Trends in pheophytin *a* concentrations were similar to those seen in chlorophyll *a* concentrations for the three monitoring stations. The maximum pheophytin *a* value in GLC was 45.2 $\mu\text{g}/\text{L}$ reported on August 2nd at Doughty Cut and the minimum was 0.71 $\mu\text{g}/\text{L}$ reported on December 6th, at Tracy Road.

Ammonia concentrations at all three stations were lowest in late spring and highest in late summer and early fall. Ammonia concentrations ranged from 0.02 to 0.60 mg/L. The mean ammonia concentration at Doughty Cut was 0.18 mg/L. Concentrations of ammonia upstream and downstream of the GLC Barrier were similar to Doughty Cut with mean values of 0.18 mg/L and 0.17 mg/L, respectively.

Nitrite-nitrate values ranged from 0.22 to 2.20 mg/L and tended to increase throughout the monitoring period at all three GLC stations. Mean values ranged from 1.34 mg/L at Doughty Cut to 1.37 mg/L at GLC Above Barrier. Nitrite-nitrate concentrations at all three GLC sites tracked closely and there was not much variation between sites.

Organic nitrogen values ranged from 0.30 to 1.50 mg/L and did not vary much throughout the monitoring period. The mean organic nitrogen concentration at Doughty Cut was 0.79 mg/L. There were only very minor differences in organic nitrogen concentrations at the sites in the immediate vicinity of the barrier. The GLC Above Barrier and Tracy Road sites had means of 0.78 mg/L and 0.74 mg/L, respectively.

Orthophosphate values were similar at all three stations. Values tended to increase during the mid summer and remained elevated through the late summer and fall. GLC orthophosphate concentrations ranged from 0.06 to 0.24 mg/L. Mean values ranged from 0.13 mg/L at Doughty Cut to 0.14 mg/L at Tracy Road and GLC Above Barrier.

Generally, water quality constituents measured at the three GLC sites tracked closely with each other and did not show any notable differences. Similar to the stations directly upstream and downstream of the DMC barrier, there were only minor differences in the constituents measured at the Grant Line Canal stations directly above (GLC Above Barrier) and below (Tracy Road). Chlorophyll *a* tended to be a little higher at Doughty Cut, but that was the result of one data outlier rather than a trend of values.

Summary of Dissolved Oxygen, Specific Conductance, and Chlorophyll

Mean dissolved oxygen concentrations at each of the ten weekly water quality sites were similar to 2003 and 2004 values. (Table 8-12). In 2005, dissolved oxygen concentrations below 5.0 mg/L were measured at four of the ten sampling locations: Middle River at Tracy Road, Old River at Tracy Road, Old River at DMC – Upstream of the Barrier, and Old River – Downstream of the DMC Barrier. Dissolved oxygen values were the lowest at Middle River at Tracy Road where concentrations ranged from 2.40 – 8.60 mg/L and averaged 5.67 mg/L.

Specific conductance concentrations were lower at most sites in 2005 than in previous years, likely due to higher San Joaquin River flows. Middle River at Union Point had the lowest recorded specific conductance values. Values at this site ranged from 159 to 417 $\mu\text{S}/\text{cm}$ and averaged 286 $\mu\text{S}/\text{cm}$. Incoming tidal water, likely from the Sacramento River, is probably the reason why specific conductance is lower at Union Point than the two upstream sites. Old River specific conductance values increased at each of the three downstream sites. The sites directly upstream and downstream of the DMC Barrier had the highest mean specific conductance values (619 $\mu\text{S}/\text{cm}$). Old River near Head, Middle River at Undine Road and the three Grant Line Canal stations had similar values with means ranging from 463 to 479 $\mu\text{S}/\text{cm}$.

Chlorophyll *a* concentrations were lower at most sites in 2005 than in previous years. Middle River at Tracy Road, Middle River at Union Point, Old River at DMC – Upstream of the Barrier, and Old River – Downstream of the DMC Barrier had the lowest chlorophyll *a* concentrations with means ranging from 1.55 to 8.82 $\mu\text{g}/\text{L}$. Old River near Head, Middle River at Undine Road, and Grant Line Canal at Doughty Cut the farthest upstream sites had the highest chlorophyll *a* concentrations with values ranging from 0.57 $\mu\text{g}/\text{L}$ to 97.2 $\mu\text{g}/\text{L}$ and means ranging from 14.5 $\mu\text{g}/\text{L}$ to 17.5 $\mu\text{g}/\text{L}$.

Continuous Water Quality Monitoring

Continuous monitoring to evaluate water quality impacts of barrier installations and operations in the South Delta was continued in 2005. This program was established for two reasons: first to determine the feasibility of collecting reliable time-series water quality data as opposed to weekly grab sampling data and second, to develop a dynamic understanding of water quality conditions affected by barrier installations, barrier operations, reservoir releases, forebay gate operations, SWP and CVP pumping operations, agricultural pumping and drainage, municipal effluent loading, hydrology, tidal fluctuations, Delta inflows as well as other variables. Continuous monitoring is capable of providing more information to identify variations and trends in water quality constituents over time, as more than 2900 data points (15-minute sampling frequency) can be gathered over a period of a month versus four or five data points from weekly grab sampling. Such a wealth of data can assist in making more informed decisions in the South Delta. This report presents data from six permanent continuous monitoring stations, which record water temperature, dissolved oxygen, pH, specific conductance, and turbidity data year-round.

Table 8-12. Average Weekly Water Quality Data 2003-05

Middle River at Undine Road	2003	2004	2005
DO	7.51	7.80	7.84
SpCond	675	683	463
Turb	20.1	21.6	16.3
Chloro	46.4	42.4	14.5
Ammonia	0.11	0.09	0.07
Nitrite-Nitrate	1.21	1.36	1.36
Organic Nitrogen	0.88	0.77	0.74
Ortho-Phosphate	0.10	0.12	0.11

Middle River at Tracy Road	2003	2004	2005
DO	6.99	6.64	5.67
SpCond	364	449	431
Turb	14.5	12.1	14.6
Chloro	6.41	3.23	3.09
Ammonia	0.10	0.09	0.08
Nitrite-Nitrate	0.44	0.43	0.58
Organic Nitrogen	0.78	0.71	0.82
Ortho-Phosphate	0.06	0.06	0.06

Middle River at Union Point	2003	2004	2005
DO	7.82	7.46	7.26
SpCond	307	326	286
Turb	8.5	8.5	7.1
Chloro	4.53	3.4	1.55
Ammonia	0.11	0.09	0.09
Nitrite-Nitrate	0.52	0.49	0.95
Organic Nitrogen	0.63	0.63	0.81
Ortho-Phosphate	0.06	0.05	0.06

Old River near Head	2003	2004	2005
DO	8.51	9.06	8.63
SpCond	633	681	465
Turb	16.2	18.9	16.6
Chloro	48.5	56.2	17.5
Ammonia	0.12	0.08	0.07
Nitrite-Nitrate	1.29	1.43	1.61
Organic Nitrogen	0.69	0.76	0.78
Ortho-Phosphate	0.10	0.12	0.11

Old River at Tracy Road	2003	2004	2005
DO	7.36	6.93	7.01
SpCond	782	854	583
Turb	23.9	24.5	19.8
Chloro	46.7	40.6	13.7
Ammonia	0.21	0.3	0.15
Nitrite-Nitrate	1.15	1.20	1.21
Organic Nitrogen	1.13	0.76	0.62
Ortho-Phosphate	0.13	0.18	0.13

Old River at DMC - Upstream	2003	2004	2005
DO	6.58	6.6	6.64
SpCond	682	740	618
Turb	18.8	20.9	19.1
Chloro	11.06	6.87	8.82
Ammonia	0.11	0.12	0.08
Nitrite-Nitrate	0.93	0.97	1.16
Organic Nitrogen	0.86	0.95	0.75
Ortho-Phosphate	0.11	0.12	0.12

Old River at DMC - Downstream	2003	2004	2005
DO	6.73	6.33	6.51
SpCond	644	724	619
Turb	17.7	18.6	17.5
Chloro	8.91	4.98	4.56
Ammonia	0.08	0.08	0.07
Nitrite-Nitrate	0.88	1.00	1.11
Organic Nitrogen	0.78	0.77	0.68
Ortho-Phosphate	0.11	0.12	0.12

GLC at Dought Cut	2003	2004	2005
DO	8.01	7.56	7.98
SpCond	698	747.6	470
Turb	21.7	25.6	20.3
Chloro	52.3	41.4	16.0
Ammonia	0.34	0.38	0.18
Nitrite-Nitrate	1.24	1.37	1.34
Organic Nitrogen	1.16	0.69	0.79
Ortho-Phosphate	0.15	0.18	0.13

GLC Above Barrier	2003	2004	2005
DO	7.56	6.91	7.76
SpCond	708	743	479
Turb	18.6	20.8	17.8
Chloro	39.4	18.0	12.3
Ammonia	0.24	0.33	0.18
Nitrite-Nitrate	1.31	1.40	1.37
Organic Nitrogen	0.98	0.76	0.78
Ortho-Phosphate	0.16	0.19	0.14

GLC at Tracy Road	2003	2004	2005
DO	6.94	6.34	7.55
SpCond	696	747	479
Turb	18.5	19.5	18.7
Chloro	32.0	26.6	11.4
Ammonia	0.20	0.31	0.17
Nitrite-Nitrate	1.34	1.43	1.36
Organic Nitrogen	0.93	0.69	0.74
Ortho-Phosphate	0.15	0.20	0.14

Sites

Three monitoring sites are located on the Old River: one on a pump platform just upstream of the barrier near the Delta Mendota Canal, one on a private boat dock at the Tracy Wildlife Association, and one on a pump-platform approximately two miles downstream of Old River at Head. Three monitoring sites are located on the Middle River: one on a pump platform in the Middle River just upstream of the Howard Road Bridge crossing, one on a pump platform in the Middle River just upstream of the Undine Road Bridge crossing, and one on a pump platform about ½ mile downstream the of Tracy Road Bridge crossing. See Figure 8-6 for site locations. Station coordinates are shown in Table 8-13.

Figure 8-6. Map of South Delta continuous water quality monitoring sites

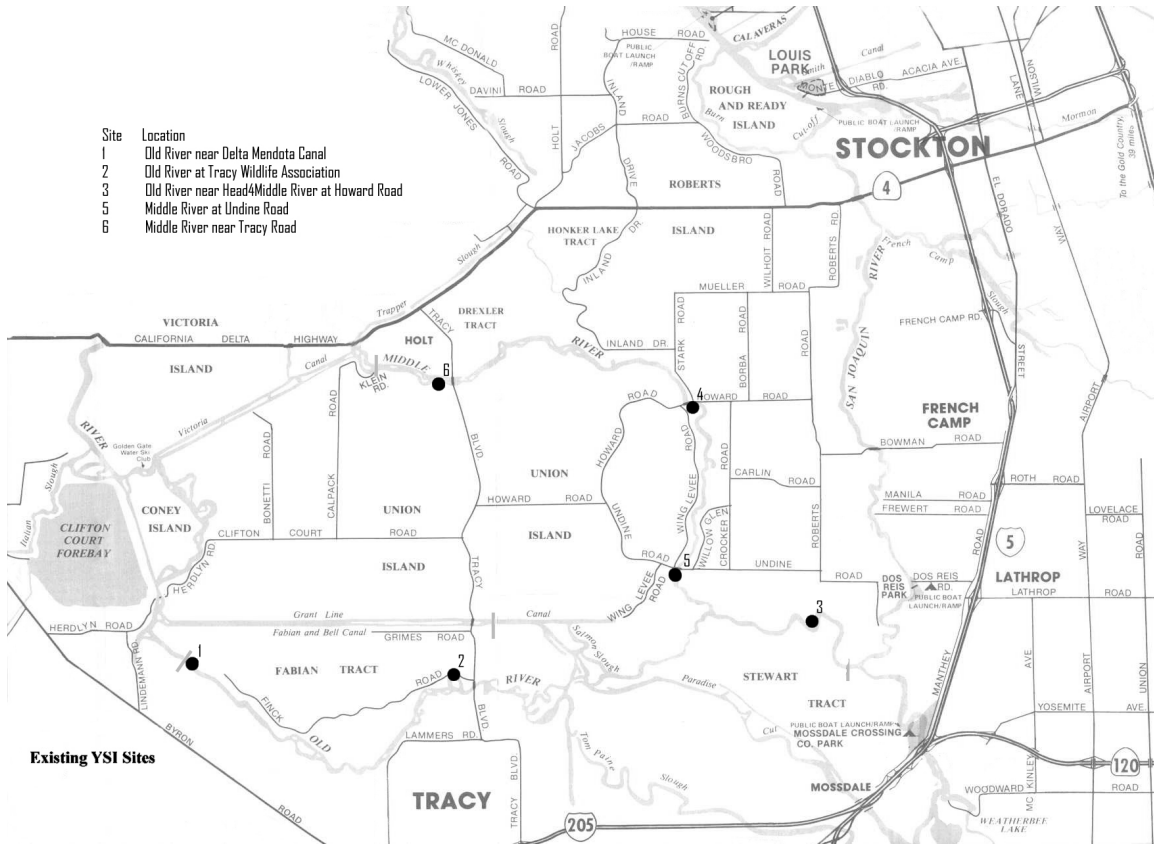


Table 8-13. Continuous monitoring station coordinates

Continuous Monitoring Station	Latitude (N)	Longitude (W)	Date Established
Middle River at Undine Road (Undine Road)	37° 50' 02.4"	121° 23' 08.6"	2002
Middle River at Howard Road (Howard Road)	37° 52' 34.5"	121° 23' 00.1"	1999
Middle River near Tracy Road (Tracy Road)	37° 52' 52.8"	121° 28' 02.7"	2003
Old River near Head (Head)	37° 49' 09.5"	121° 21' 37.2"	2001
Old River at Tracy Wildlife Association (TWA)	37° 48' 10.2"	121° 27' 26.8"	1999
Old River upstream of Delta Mendota Canal Barrier (DMC)	37° 48' 37.0"	121° 32' 32.0"	2000

Instrumentation

Yellow Springs Instruments 6600 “sondes” (continuous multi-parameter water quality monitoring instruments) were operated during the year to gather data at six sites in the South Delta. YSI 6600 sondes are approximately two feet long and three and half inches in diameter. They are completely submersible and self-contained, operating on a minimum of 9 volts of battery power from 8 C-cell alkaline batteries. They are capable of measuring up to 15 water quality parameters including water temperature, dissolved oxygen, pH, specific conductance, turbidity, chlorophyll, depth, open-channel flow, nitrate, ammonium/ammonia, oxidation/reduction potential, chloride, salinity, total dissolved solids, and electrical conductivity. Deployment data are logged in each sonde’s internal memory. Sondes are capable of sampling at many different user-specified frequencies. During 2000, an hourly sampling frequency was used

for all stations, approximately 732 samples per month. In 2001, the sampling frequency was changed to every fifteen minutes, approximately 2920 samples per month.

The constituents measured at the six South Delta continuous monitoring sites were water temperature, dissolved oxygen, pH, specific conductance, and turbidity. In July 2005, chlorophyll monitoring was added at three sites: Old River near Head, Old River at Tracy Wildlife Association, and Middle River at Howard Road. As in 2000-04, continuous monitoring in 2005 proved to be a good test of the YSI 6600 sondes for time-series data collection within the Delta. Weekly field data gathered from each site confirmed the accuracy, reliability, and longevity of the instruments for Delta waterway's use.

A sonde can be powered by a new set of batteries from one to three months, depending upon the number of parameters being monitored, the sampling frequency, and the water temperature. However, during the summer months biological growth can foul certain probes within a week, the dissolved oxygen probe being the most susceptible to fouling. Thus, a sonde's deployment period can be limited either by operational style and/or ambient conditions within the water-body under study. In 2003, Central District staff shipped all 6600 sondes back to YSI for an upgrade to the new 6600 EDS (Extended Deployment System) model. The upgrade included a wiper that wipes the dissolved oxygen, pH and conductivity sensors, which reduced the amount of biological fouling on the probes. This has further ensured the collection of accurate and precise data from 2003 to 2005. For this project, a three-week deployment period was used year-round as our standard for monitoring stations in the South Delta. It is important to note however, that monitoring sites were visited weekly by Central District staff for routine maintenance and field verification of instrument operation. Field equipment used included a YSI-63 handheld unit that measured water temperature, pH, and specific conductance, a HACH modified Winkler titration kit to check dissolved oxygen concentrations, and a HACH 2100P turbidimeter.

Sonde data can be downloaded in the field either by laptop computer or with a YSI-610 or YSI-650 interfacing hand-held unit. Usually though, each sonde was exchanged in the field with a fresh lab-calibrated instrument, then downloaded and post-deployed in the Central District lab. Post-deployments were performed to determine probe drift and biofouling errors by checking individual probe readings against calibration standards, which ultimately verified instrument accuracy. In general, probe drift has not been observed with these instruments.

Installations

At each monitoring site, a sonde is vertically housed within a 4" diameter PVC pipe, in the water column, suspended at a depth of approximately 3 feet. To discourage vandalism the pipes are covered at the top with an end-cap and locked shut with two Masterlocks through two 0.5"-diameter bolts. Installation pipes were drilled with 2.25" diameter holes along the length of the pipe and spaced approximately 8" – 10" on center. Four sets of holes are drilled longitudinally at 90° angles from each other. These holes allow ambient water to adequately contact the sonde sensors to ensure accurate data collection. At each site, the sonde installation pipe is either lag-bolted into an existing float structure (e.g. wooden boat dock) or steel-banded to a pump platform durable enough to withstand long-term usage.

Upon inspection of the 2000/2001 installations, a considerable amount of biological growth in the form of algae, bryophytes, and freshwater sponges had completely covered the solid-surface areas of the pipes and even managed to partially cover over some of the exchange-holes. It was recommended by YSI technicians that antifouling paint could dramatically decrease the amount of biological growth on the installation pipes, thereby reducing the possible formation of microcosms within the pipes that do not share the same water quality conditions as the

surrounding ambient water. Visual inspections of the installation pipes in 2002-2005 showed that antifouling paint has been effective tool in decreasing biological growth.

Continuous Monitoring Data

Water year 2005 (October 1st, 2004 – September 30th, 2005) was classified as a wet year for the San Joaquin Valley. Unimpaired runoff was 9.25 million acre-feet and runoff was greatest from April through July. For the Sacramento Valley water year 2005 was classified as an above normal year and unimpaired runoff totaled 18.44 million acre-feet. San Joaquin River flows past Vernalis were highest from April to June averaging 10,232 cfs. Refer back to Figure 8-3 for flow and specific conductance data for the San Joaquin River at Vernalis in 2005. Flows were lowest from August 15th to December 15th averaging about 2,242 cfs. Total daily exports for the Central Valley Project (CVP) and State Water Project (SWP) averaged 9,291 cfs from January to March. In April and May exports were the lowest during the year averaging 5,814 cfs and 3,046 cfs, respectively. Figure 8-7 depicts total daily exports (cfs) for the SWP and CVP. From June through December, daily exports averaged 10,725 cfs.

The USEPA has established National Ambient Water Quality Criteria for inorganic constituents, such as dissolved oxygen and pH, to protect freshwater aquatic life. However, there is considerable variability in dissolved oxygen tolerances amongst fish and other aquatic life. For a warm water system like the Delta, dissolved oxygen criteria for early aquatic life stages (embryos, larvae, and less than 30-day old juveniles) was set at 5 mg/L, and, for other life stages (older juveniles and adults), the dissolved oxygen criterion is 3 mg/L. The recommended criterion for pH is an instantaneous maximum between 6.5 and 9.0. The recommended agricultural water limit for specific conductance is 700 $\mu\text{S}/\text{cm}$. Discussion of dissolved oxygen, pH and specific conductance water quality data will focus on these criteria.

Middle River

Water temperatures in the Middle River reached a maximum of 29.58 °C on July 14th at 17:15 PST at Tracy Road and a minimum of 7.61 °C on December 14th at 9:00 PST at Howard Road. See Figures 8-8 to 8-10. A visual comparison of the 2005 water temperature plots for each of the three Middle River monitoring sites reveals similar trends. This would seem reasonable, as all three sites are located within 10 miles of each other and thus are subject to relatively similar meteorological conditions throughout the year. The finer perturbations of water temperatures at each site would hence be related to site-specific conditions (water volume, flow, shading from vegetative cover, etc.). Temperature patterns at the Middle River sites followed seasonal trends, with the highest temperatures occurring in summer and the lowest in late fall and winter. Monthly mean temperatures were highest in July ranging from 23.79 °C at Undine Road to 25.80 °C at Tracy Road and lowest in January ranging from 8.26 °C at Tracy Road to 8.39 °C at Howard Road. The mean temperatures for the monitoring period ranged from 16.70 °C at Undine Road to 17.40 °C at Tracy Road.

Dissolved oxygen data for the Middle River sites during 2005 are also plotted in Figures 8-8 to 8-10. DO concentrations reached a maximum of 15.97 mg/L on September 2nd at 15:00 PST at Undine Road and were at a minimum of 0.13 mg/L on July 29th at 0:45 PST at Howard Road. There were 51, 915 and 3,271 readings at Undine Road, Howard Road, and near Tracy Road, respectively; from June through October when the sondes recorded DO concentrations less than 5 mg/L. See Figure 8-11. At Middle River near Tracy Road: 211 sonde readings (of the 3,271 below 5 mg/L) were below 3 mg/L. At Middle River at Howard Road: 331 sonde readings (of the 915 below 5 mg/L) were below 3 mg/L. There were no DO concentrations below 3 mg/L at

Undine Road. The lowest monthly mean DO was 5.02 mg/L in August at Tracy Road and the highest was 12.78 mg/L in May at Howard Road. Overall mean DO concentrations for Middle River ranged from 7.58 mg/L at Tracy Road to 9.18 mg/L at Howard Road.

During the late spring through early fall, DO concentrations showed marked diel variation. During a typical summer day, DO concentrations reached a maximum in the late afternoon and a minimum during the early morning. Diel variation in dissolved oxygen concentrations is likely due to algal photosynthesis and respiration and water temperature variation. Dissolved oxygen concentrations were supersaturated throughout the summer at Undine Road, whereas dissolved oxygen concentrations at Howard Road and Tracy Road were lowest during the summer. In mid-fall through winter there was less pronounced diel variation in DO values, which may be due to the fact there is less daily variation in water temperature and generally, lower chlorophyll *a* / pheophytin *a* levels (less algal biomass) during the colder months.

Figures 8-8 to 8-10 also depict 2005 pH data in the Middle River. Similar to water temperature and dissolved oxygen data, pH data at Undine Road and Howard Road exhibited greater diel fluctuations during summer through early fall and noticeably less during late fall and winter. This is likely a direct function of algal productivity, in that, as algae consume CO₂ from water, they produce dissolved oxygen as a byproduct of primary productivity. Less CO₂ in the water drives the pH higher, as the water becomes more alkaline. pH values at Middle River at Tracy Road tended to have greater diel fluctuation in the fall rather than the summer. Recorded pH data ranged from a high of 9.01 on August 17th at 17:30 PST at Undine Road to a low of 6.73 on October 24th at 7:30 PST at Tracy Road. Four pH values greater than 9.0 were recorded at Undine Road. Mean pH values ranged from 7.32 at Tracy Road to 7.66 at Undine Road.

Figure 8-7. Totals: State Water Project and Central Valley Project

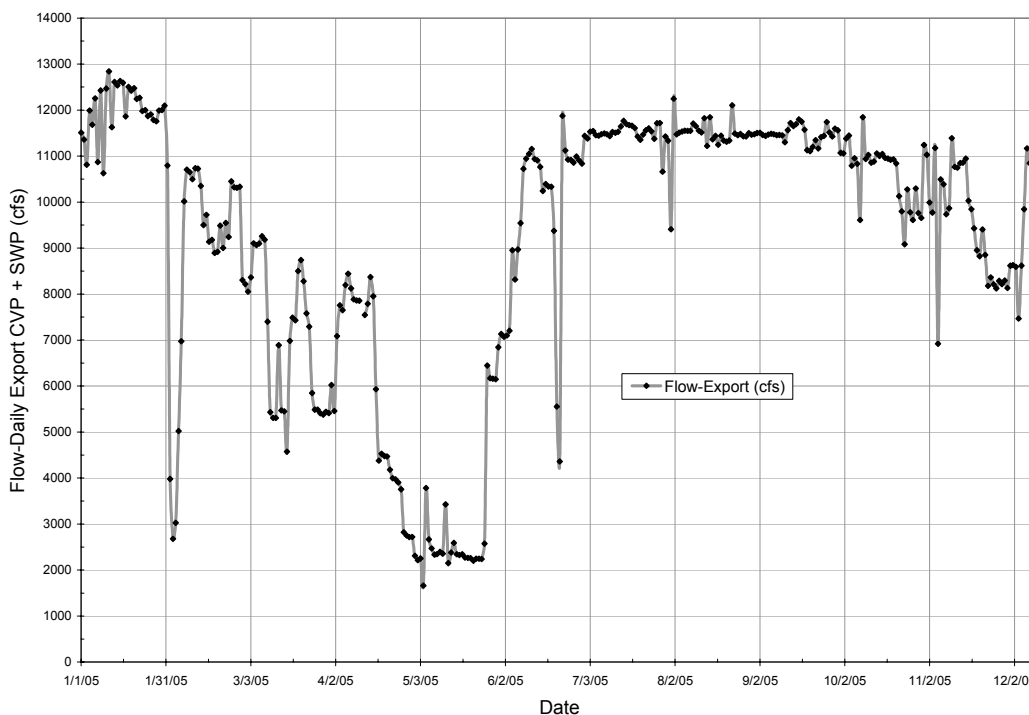


Figure 8-8. Middle River at Undine Road: water temperature, dissolved oxygen and pH continuous water quality data

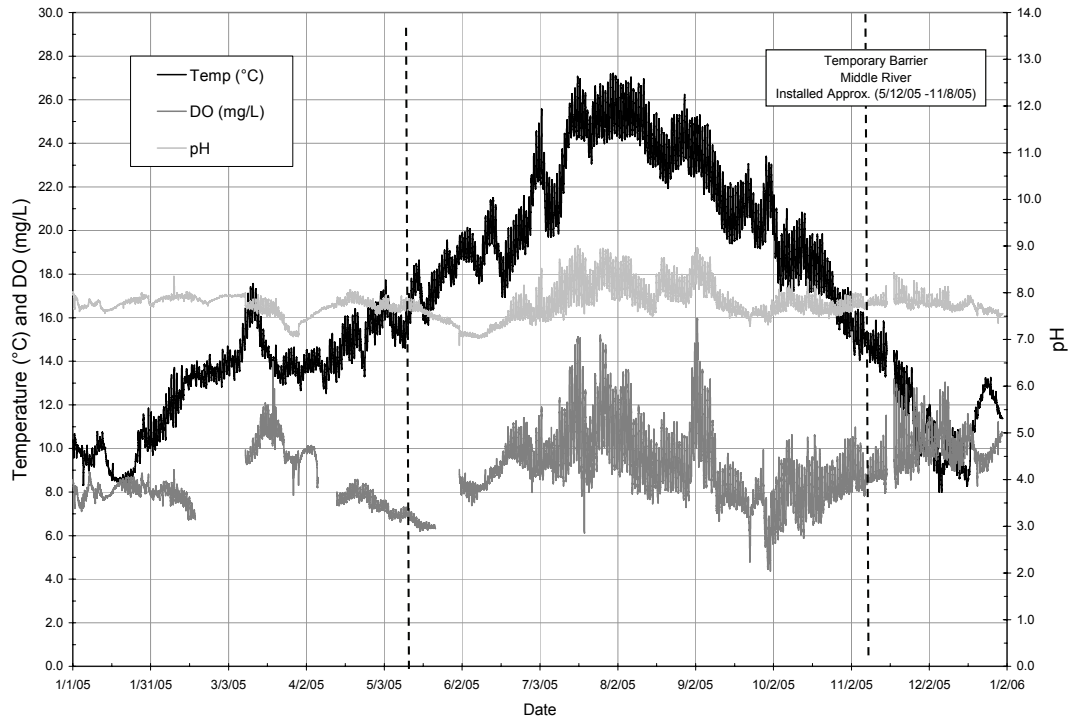


Figure 8-9. Middle River at Howard Road: water temperature, dissolved oxygen and pH continuous water quality data

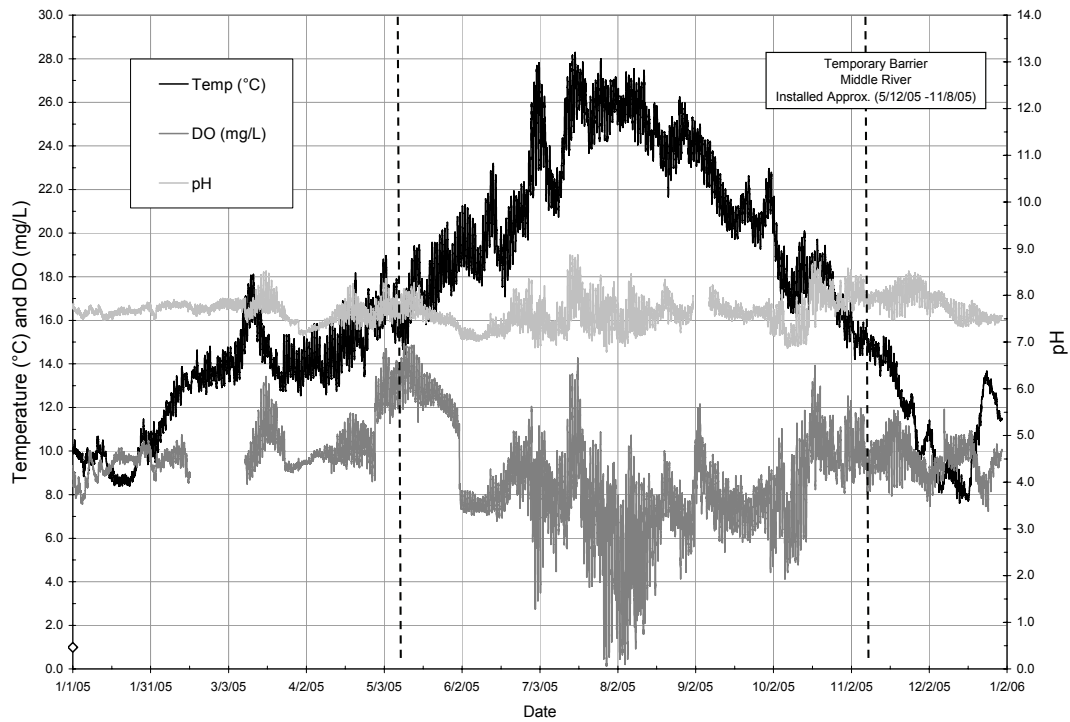


Figure 8-10. Middle River near Tracy Road: water temperature, dissolved oxygen and pH continuous water quality data

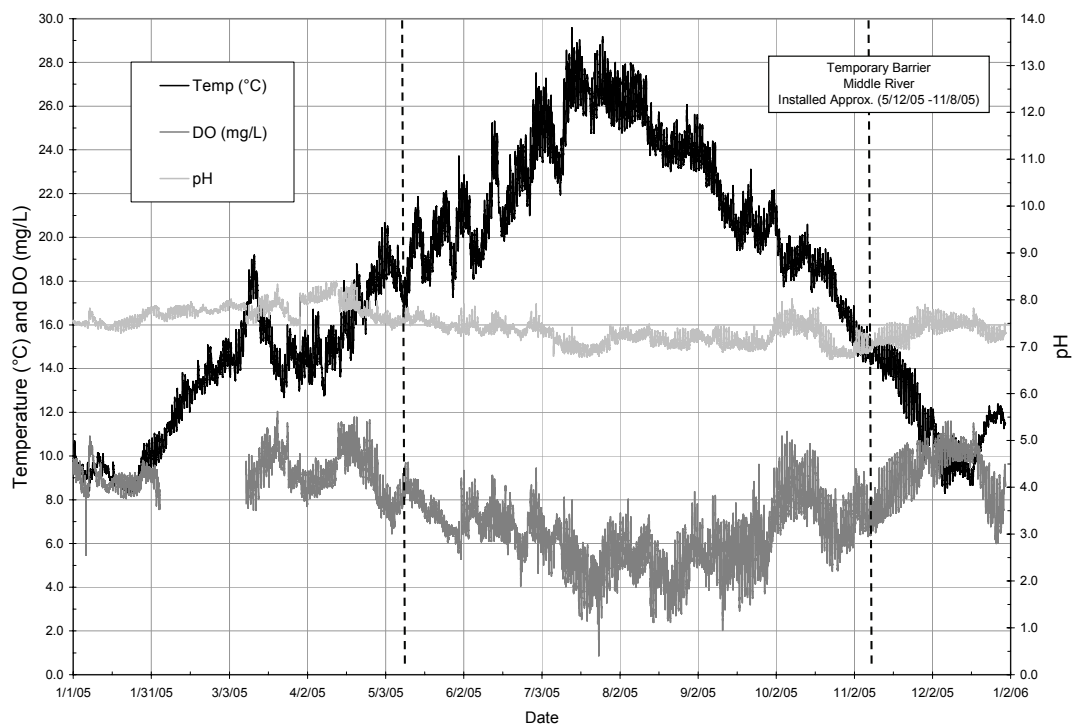
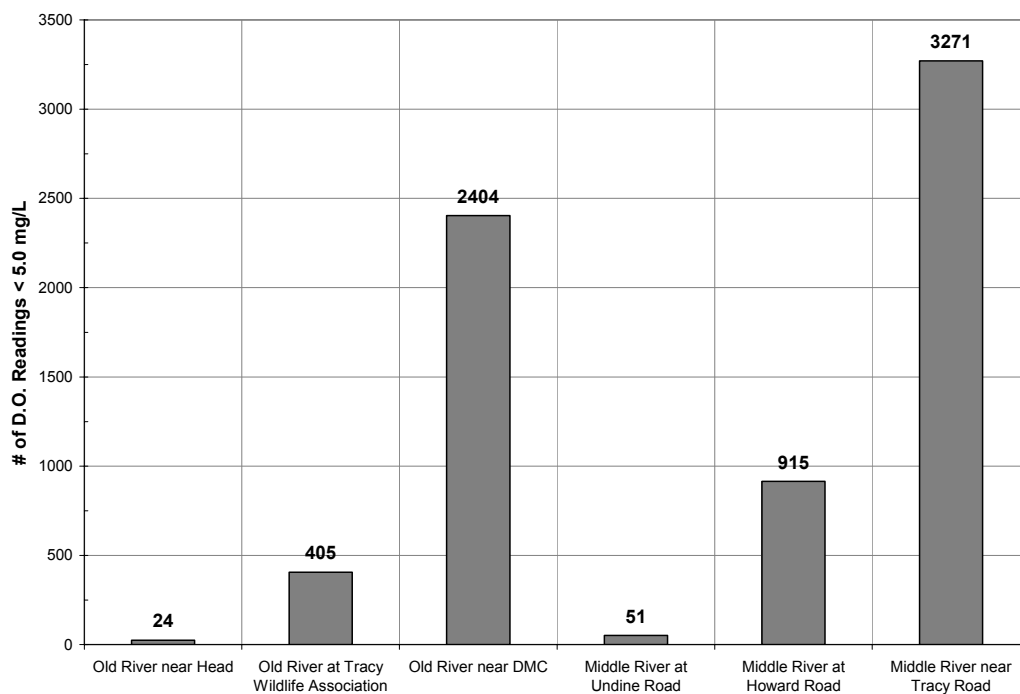


Figure 8-11. Dissolved oxygen concentrations below 5.0 mg/L



Specific conductance data for the Middle River sites is shown in Figures 8-12 to 8-14. A maximum of 1,664 $\mu\text{S}/\text{cm}$ was recorded on January 29th at 18:00 PST at Howard Road. The minimum-recorded specific conductance was 100 $\mu\text{S}/\text{cm}$ on May 26th at 18:45 PST at Undine Road. The means for the monitoring period ranged from 483.5 $\mu\text{S}/\text{cm}$ at Undine Road to 565.3 $\mu\text{S}/\text{cm}$ at Howard Road. Howard Road had spikes in specific conductance throughout the year (compare Figures 8-12 and 8-13) and had a higher mean value than either the upstream or downstream monitoring locations. This would seem to suggest that localized influences such as agricultural pumping and return flows are influencing specific conductance in this area. The fluctuations in specific conductance at Middle River near Tracy Road (compare Figures 8-11 and 8-14) are likely due to tidal influences.

Monthly mean values were the highest in January and February when the barriers were not installed. The highest monthly mean specific conductance value was 889.8 $\mu\text{S}/\text{cm}$ in January at Howard Road. From April through June there were higher San Joaquin River flows past Vernalis and decreases (April and May only) in SWP and CVP daily exports (Figures 8-3 and 8-7). Specific conductance decreased considerably during this period with means in April through June ranging from 188.5 $\mu\text{S}/\text{cm}$ in May at Undine Road to 369.7 $\mu\text{S}/\text{cm}$ in April at Tracy Road. Throughout the summer specific conductance values began to rise likely, in part due to lower San Joaquin River flows, CVP and SWP pumping, and agricultural pumping and return flows. While the barriers were operational the highest monthly mean was 603.3 $\mu\text{S}/\text{cm}$ in September at Howard Road. After the barriers were taken out in November specific conductance values began to rise until December 20th, after which high San Joaquin River flows and lower specific conductance at Vernalis during the end of the year resulted in a sharp decline in conductivity values at all three Middle River monitoring sites.

Figures 8-12 to 8-14 also depicts turbidity data at the Middle River sites. Turbidities ranged from a high of 194.7 NTU on January 12th at 0:00 PST to a low of 0.1 NTU on October 15th at 5:45 PST, both at Howard Road. Several times in 2005, turbidities exhibited pulse-peaks. Generally, single turbidity spikes can be attributed to a foreign object, such as a leaf or fish passing before the optic sensors as the instrument is taking a reading. These anomalies are usually omitted. However, there are moments during the year where several continuous readings reveal a peaking-trend. The largest of these incidences occurred from October 21st to the 29th at Undine Road. Such occurrences during colder months are generally attributed to storm events, whereas during summer months these peaks in part can be attributed to algal blooms. Yet, in highly productive agricultural regions such as the Delta these turbidity peaks could also be caused by agricultural drainage near the monitoring site(s). Mean turbidity values ranged from 11.6 NTU at Tracy Road to 25.7 NTU at Undine Road. Turbidity values were generally high throughout the late winter, spring and summer with mean values ranging from a low of 9.5 NTU in August at Tracy Road to a high of 49.2 NTU in January at Undine Road. In the fall and early winter, turbidity values were the lowest with means ranging from 3.3 NTU in November at Howard Road to 17.0 NTU in September at Undine Road.

Figure 8-12. Middle River at Undine Road: specific conductance and turbidity continuous water quality data

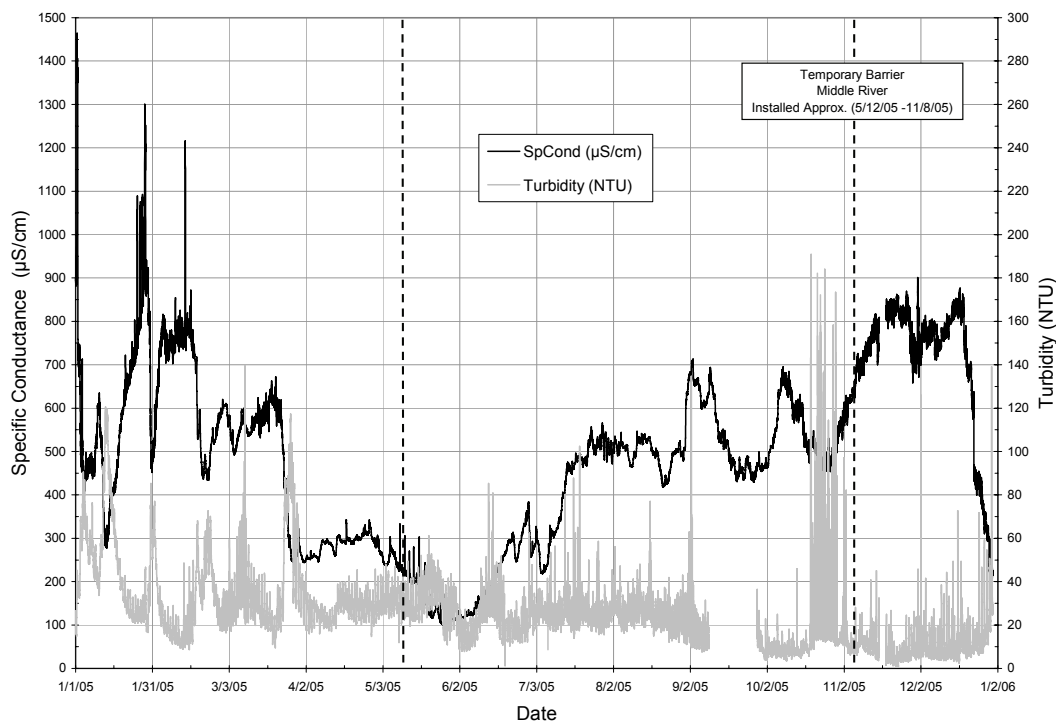


Figure 8-13. Middle River at Howard Road: specific conductance and turbidity continuous water quality data

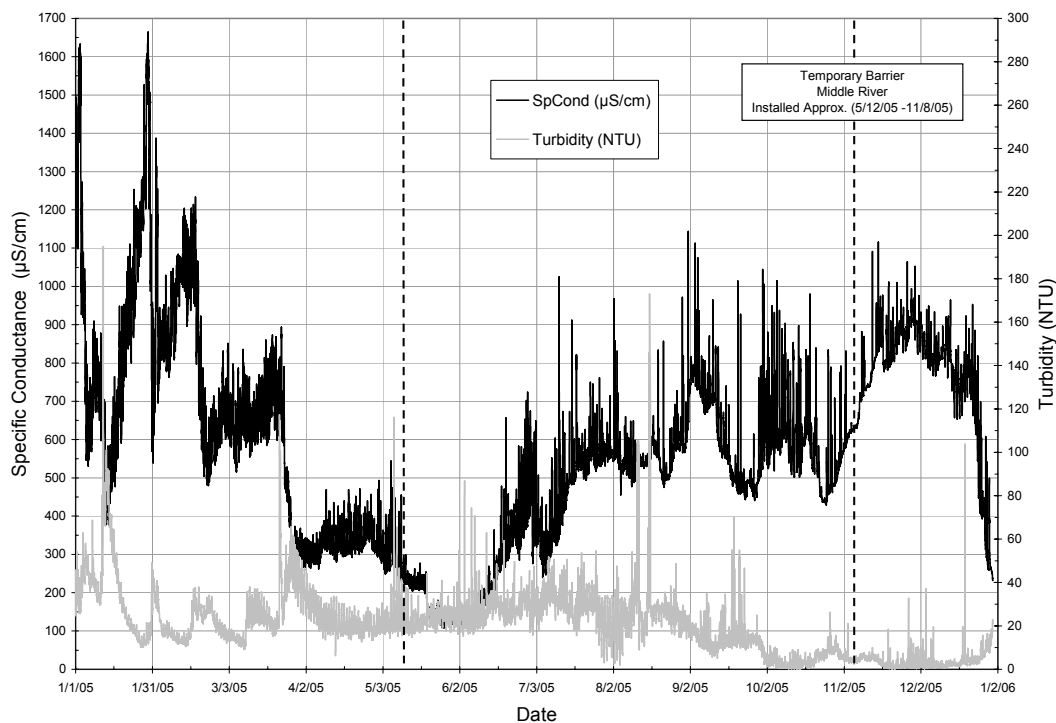
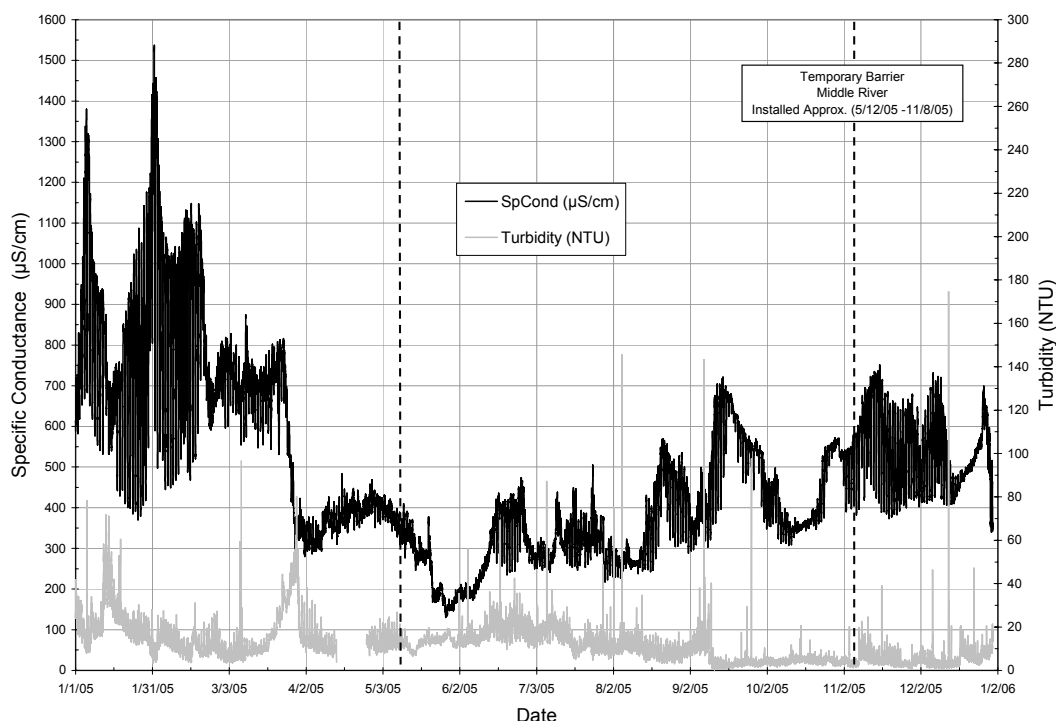


Figure 8-14. Middle River near Tracy Road: specific conductance and turbidity continuous water quality data



Old River

Water temperatures in the Old River reached a maximum of 27.49 °C on July 16th at 15:00 PST and a minimum of 8.54 °C on January 21st at 8:15 PST, both at TWA. See Figures 8-15 to 8-17. Temperature patterns at the Old River monitoring stations were similar to the Middle River stations previously discussed. July and August water temperatures were the warmest with means ranging from 23.49 °C to 24.83 °C, while January temperatures were the coldest averaging about 9.70 °C. The mean water temperatures during the monitoring period ranged from 16.99 °C at Head to 18.43 °C at DMC. Note: The Old River near DMC mean was higher because there was no January or February data due to an instrument malfunction.

Dissolved oxygen data for the Old River during 2005 are also plotted in Figures 8-15 to 8-17. DO concentrations reached a maximum of 16.61 mg/L on March 18th at 14:00 PST at TWA and were at a minimum of 1.82 mg/L on July 23rd at 19:00 PST at DMC. There were 24, 405 and 2,404 readings at Old River near Head, TWA, and DMC, respectively; from July through November when the sondes recorded DO concentrations less than 5 mg/L (Figure 8-11). At Old River near DMC: 21 sonde readings (of the 2,404 below 5 mg/L) were below 3 mg/L. There were no DO concentrations below 3 mg/L at Head or TWA. The lowest monthly mean was 5.57 mg/L in August at DMC and the highest was 10.94 mg/L in March at TWA. Mean DO concentrations for the Old River in 2005 ranged from 7.92 mg/L at DMC to 9.38 mg/L at Head.

Diel variation in DO concentrations was most pronounced during the summer through early fall with values fluctuating considerably, where as in late fall and winter, there was less variation. Diel variation in dissolved oxygen concentrations is likely due to algal photosynthesis and respiration and water temperature variation

Figures 8-15 to 8-17 also displays 2005 pH data in the Old River. Recorded pH data ranged from a high of 9.12 on March 22nd at 14:00 PST to a low of 6.94 on September 24th at 8:15 PST, both at TWA. 30 pH values greater than 9.0 were recorded at TWA. There were no recorded pH values greater than nine at Head or DMC. pH values in Old River ranged from 7.60 at TWA to 7.64 at both Head and DMC.

Specific conductance data for the Old River monitoring sites are shown in Figures 8-18 to 8-20. A maximum of 1410.2 $\mu\text{S}/\text{cm}$ was recorded on November 25th at 4:30 PST at TWA. The minimum-recorded specific conductance was 101.0 $\mu\text{S}/\text{cm}$ on May 26th at 17:15 PST at Head. The means for the monitoring period ranged from 485.5 $\mu\text{S}/\text{cm}$ at Head to 616.7 $\mu\text{S}/\text{cm}$ at TWA. TWA had spikes in specific conductance throughout the year (compare Figures 8-18 and 8-19) and had a higher mean value than either the upstream or downstream monitoring locations. This would seem to suggest that localized influences such as agricultural pumping and return flows are influencing specific conductance in this area. The fluctuations in specific conductance at DMC (compare Figures 8-18 and 8-20) are likely to be due to tidal influences. Specific conductance at the Head monitoring station is probably influenced primarily by the San Joaquin River. A visual comparison between Figure 8-18 and Figure 8-3 shows that the specific conductance patterns at this site and at the San Joaquin River at Vernalis are quite similar.

Monthly mean values were highest in January through March and October through December. The highest monthly mean specific conductance value was 858 $\mu\text{S}/\text{cm}$ in November at TWA. From April through June there were higher San Joaquin River flows past Vernalis and decreases (April and May only) in SWP and CVP daily exports (Figures 8-3 and 8-7). Specific conductance decreased considerably during this period with means in April through June ranging from 196.9 $\mu\text{S}/\text{cm}$ in May at Head to 426 $\mu\text{S}/\text{cm}$ in April at DMC. Throughout the summer, specific conductance values began to rise likely, in part due to lower San Joaquin River flows, CVP and SWP pumping, and agricultural pumping and return flows. While the barriers were operational the highest monthly mean was 853.1 $\mu\text{S}/\text{cm}$ in October at TWA. After the barriers were taken out in November, specific conductance values began to rise until December 20th, after which high San Joaquin River flows and lower specific conductance at Vernalis during the end of the year resulted in a sharp decline in conductivity values at all three Old River monitoring sites.

Figure 8-15. Old River near Head: water temperature, dissolved oxygen and pH continuous water quality data

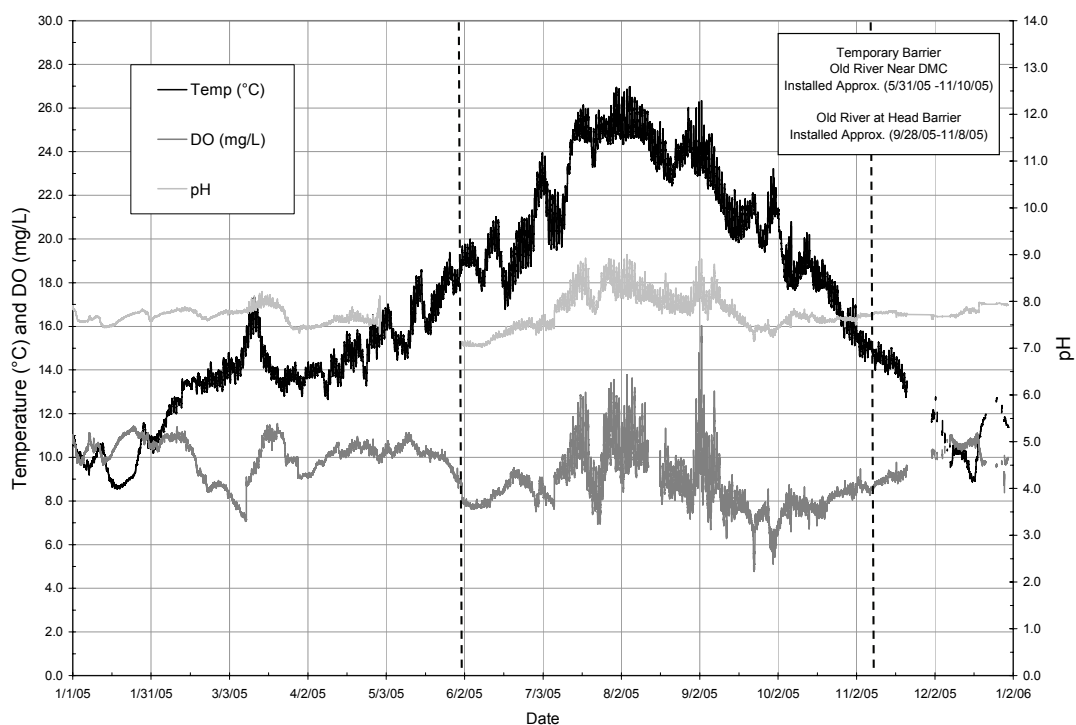


Figure 8-16. Old River at Tracy Wildlife Association: water temperature, dissolved oxygen and pH continuous water quality data

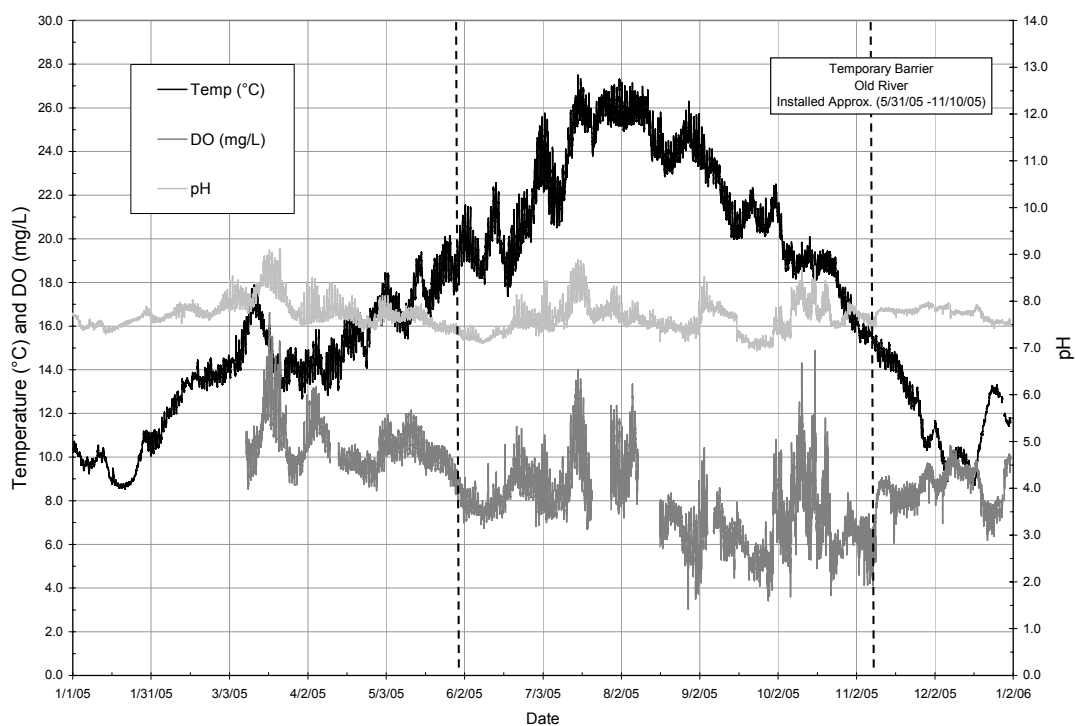


Figure 8-17. Old River Barrier near Delta Mendota Canal: water temperature, dissolved oxygen and pH continuous water quality data

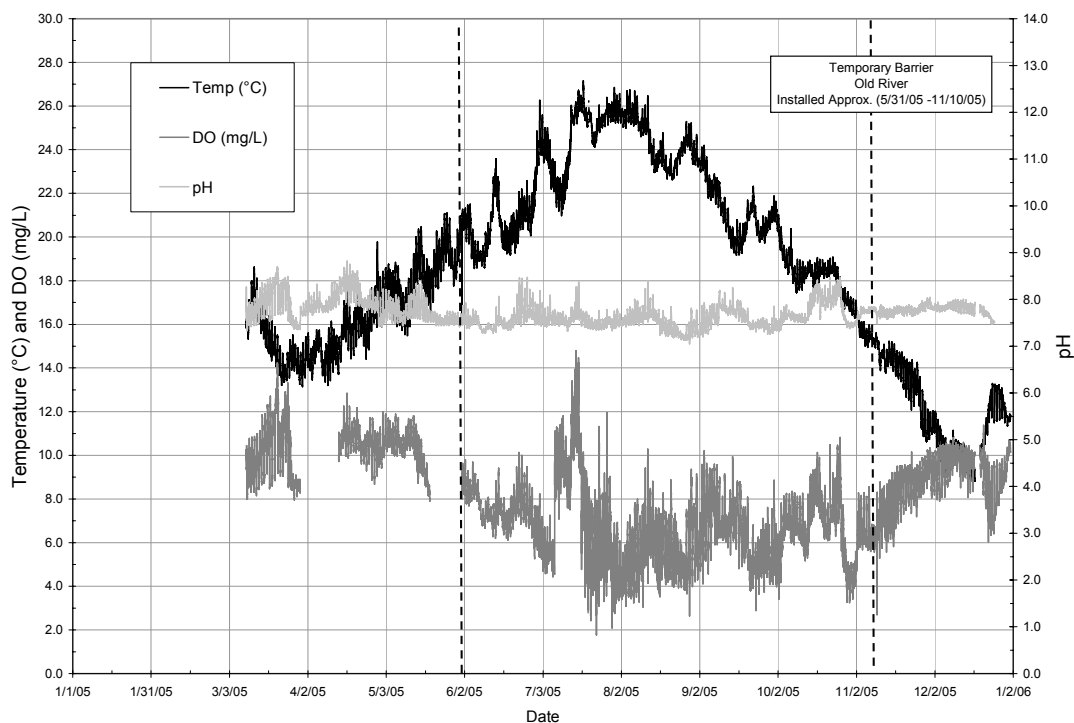


Figure 8-18. Old River near Head: specific conductance and turbidity continuous water quality data

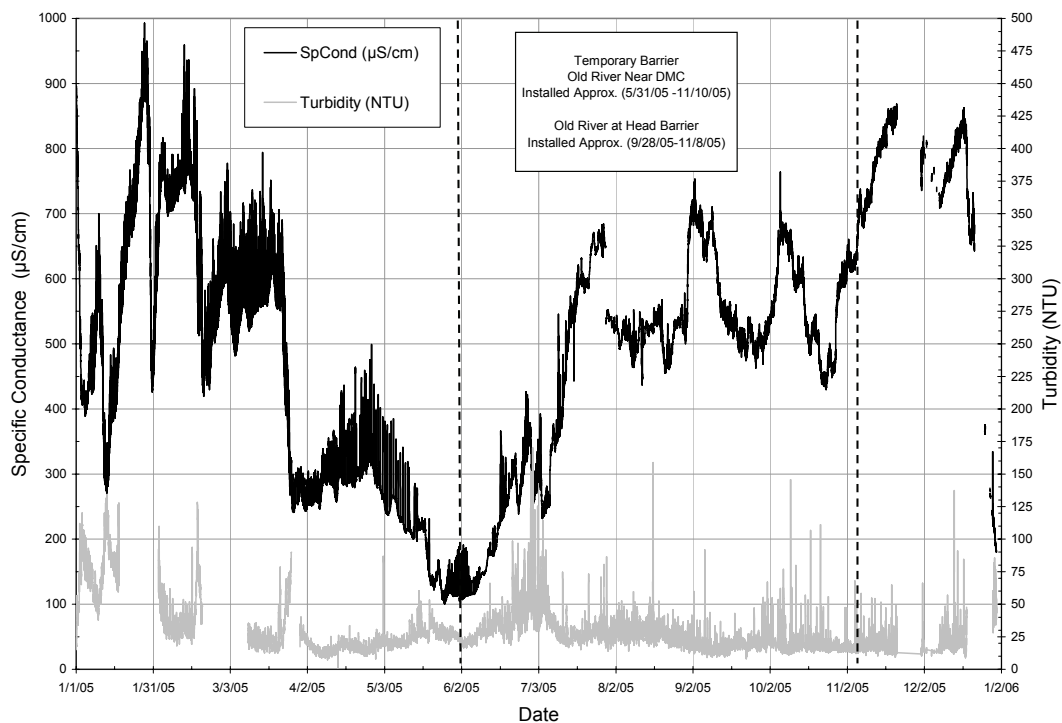


Figure 8-19. Old River at Tracy Wildlife Association: specific conductance and turbidity continuous water quality data

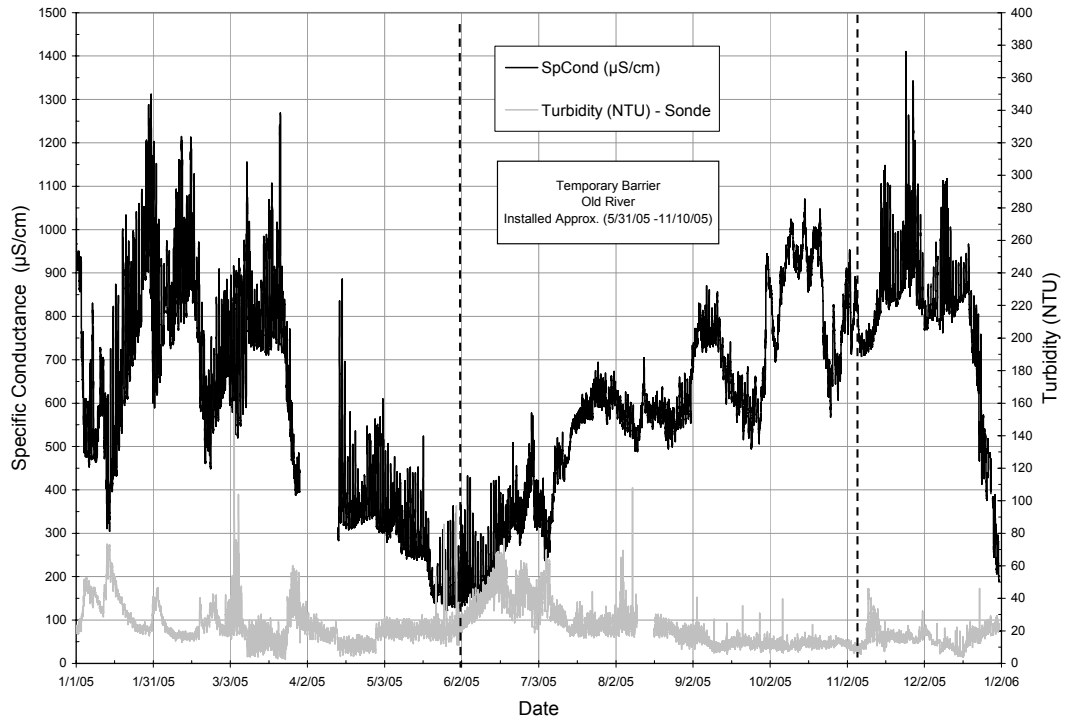
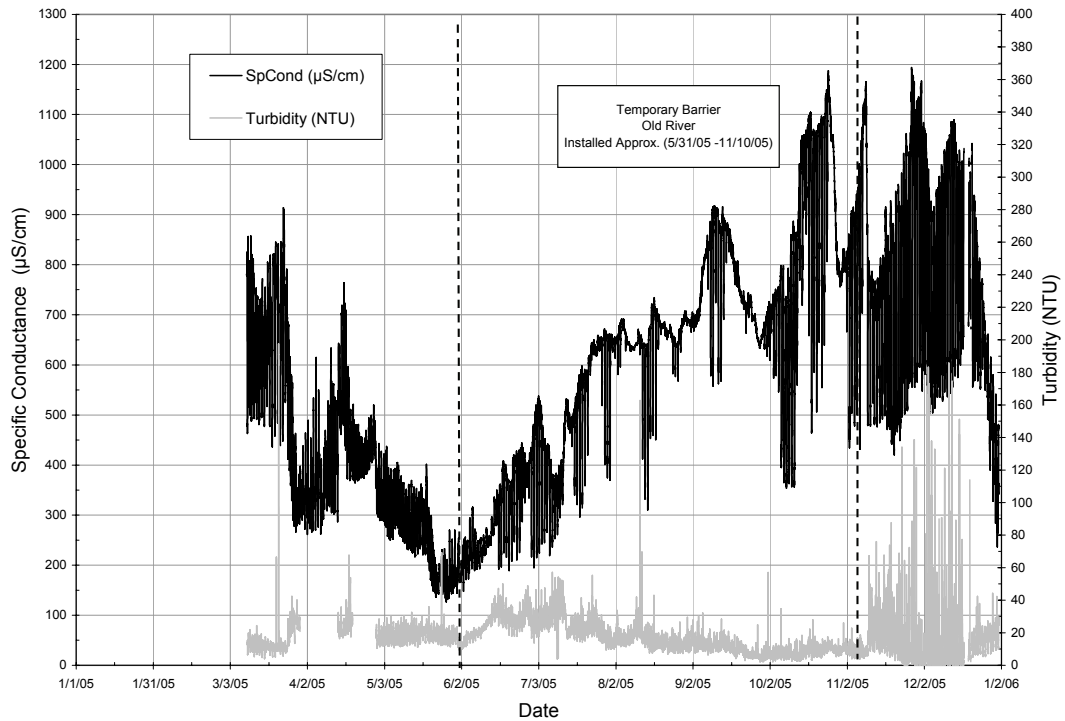


Figure 8-20. Old River Barrier near Delta Mendota Canal: specific conductance and turbidity continuous water quality data



Figures 8-18 to 8-20 also depicts turbidity data in the Old River. Turbidities ranged from a high of 197.3 NTU on March 22nd at 2:30 PST to a low of -1.8 NTU on December 8th at 0:30 PST, both at DMC. Note: the minimum value of -1.8 can be attributed to clear water and probe drift. Generally, monthly mean turbidity readings were highest in the winter and summer ranging from 15.1 NTU in August at DMC to 75.6 NTU in January at Head. The lowest reading occurred in fall with means ranging from 8.3 NTU at DMC to 19.1 NTU at Head. In 2005, turbidity means ranged from 28.7 NTU at Head to 16.6 NTU at DMC.

In July 2005, chlorophyll sampling was implemented at three South Delta monitoring locations: Old River near Head, Old River at TWA, and Middle River at Howard Road. See Figures 8-21 to 8-23. The YSI chlorophyll probe provides an estimate of chlorophyll concentrations by measuring fluorescence. To get a more precise representation of chlorophyll *a* concentrations in the Southern Delta, grab samples for chlorophyll *a* were taken bi-monthly at each of three sites for analysis at Bryte lab. Regression analysis was used to determine a relationship between continuous chlorophyll values from the YSI 6600 sonde and extracted chlorophyll *a* values. The equation based on regression analysis is also shown in Figures 8-21 to 8-23 along with the corresponding coefficient of multiple correlation (R^2). The R^2 value is a measure of the proportion of the total variability in Y that is explained by X and is direct function of the correlation between the variables. R^2 values can range from 0 to 1, with 0 meaning there was no correlation between the x and y variables and 1 meaning there was a perfect correlation between the x and y variables. Old River near Head, Old River at TWA, and Middle River at Howard Road had R^2 values of 0.9841, 0.9034, and 0.809, respectively; indicating a strong correlation between the two variables.

Chlorophyll *a* concentrations ranged from a high of 329.1 $\mu\text{g/L}$ on August 11th at 5:45 PST to a low of -4.7 $\mu\text{g/L}$ on December 29th at 20:00 PST, both at TWA. Note: the negative chlorophyll *a* minimum was due to probe drift and very low chlorophyll concentrations. Algal biomass as indicated by chlorophyll *a* concentrations was highest in July with monthly means ranging from 25.5 $\mu\text{g/L}$ at Howard Road to 53.5 $\mu\text{g/L}$ at Head. The lowest chlorophyll *a* concentrations occurred in November and December with monthly means ranging from 3.9 $\mu\text{g/L}$ at Head to 7.3 $\mu\text{g/L}$ at TWA. Overall, from July through December, means ranged from 23.6 $\mu\text{g/L}$ at Head to 10.6 $\mu\text{g/L}$ at Howard Road.

Conclusions

Tables 8-14 to 8-17 provide a basic statistical summary of the 2005 water quality data collected from the six continuous monitoring sites. The monthly maximum, average, and minimum, and standard deviation are displayed for each water quality parameter. Yearly statistics are included at the bottom of the table. Additionally, Figures 8-24 to 8-34 show graphical representations of the data in Tables 8-14 to 8-17. Refer to these tables and figures in the following discussion of 2005 time-series water quality data for the South Delta.

Water temperature readings in the Middle River and Old River were primarily influenced by air temperature and followed seasonal patterns. Temperature variation between the six continuous sites was likely due to site-specific localized differences. At all six monitoring locations, water temperature readings tracked closely throughout the year. Refer to Figures 8-24 and 8-25 and Tables 8-14 and 8-15. In 2005, mean water temperatures ranged from 16.70 °C at Undine Road to 18.43 °C at DMC. Note: The Old River at DMC mean was higher because there was no January or February data due to an instrument malfunction.

Figure 8-21. Old River near Head: chlorophyll a continuous water quality data

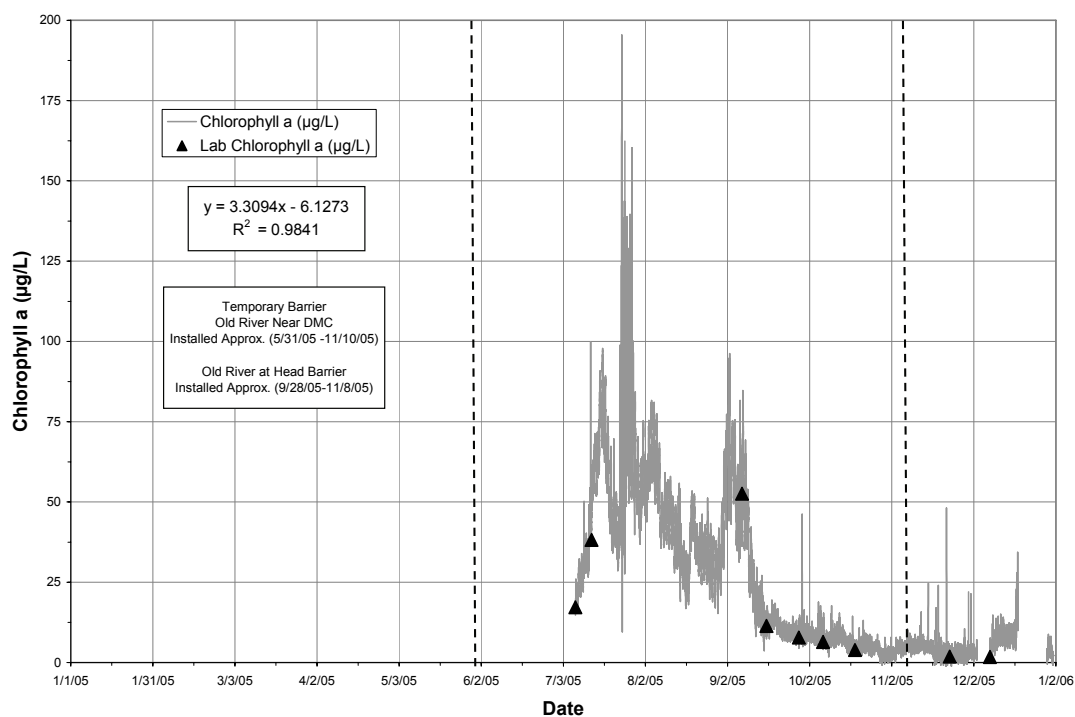


Figure 8-22. Old River at Tracy Wildlife Association: chlorophyll a continuous water quality data

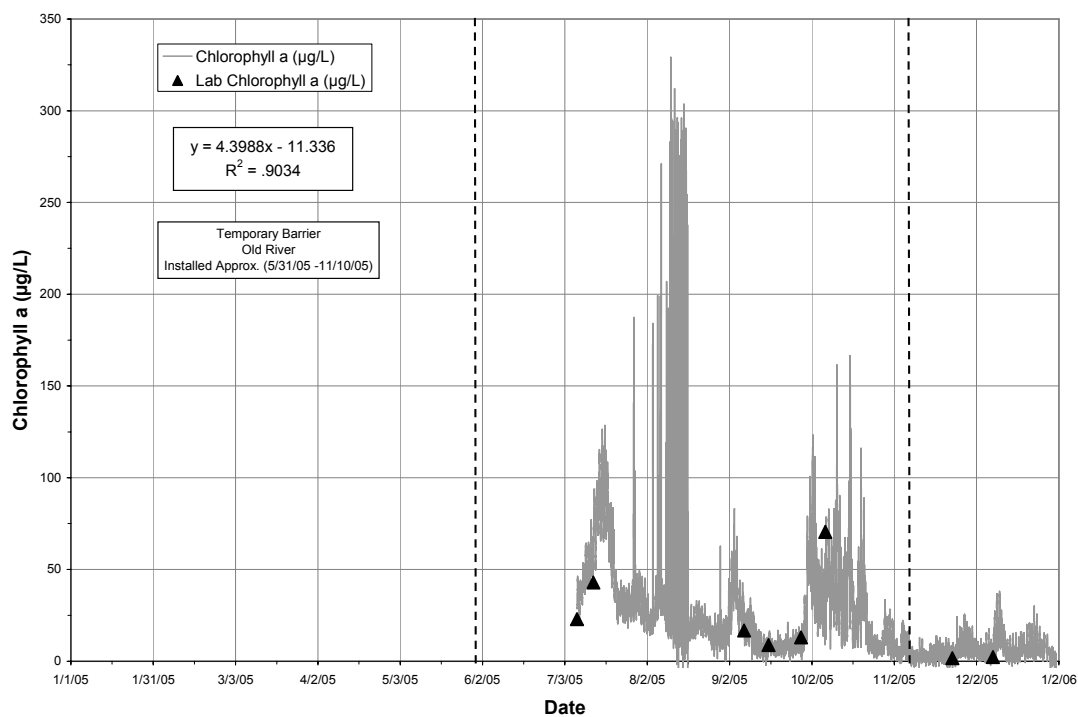


Figure 8-23. Middle River at Howard Road: chlorophyll a continuous water quality data

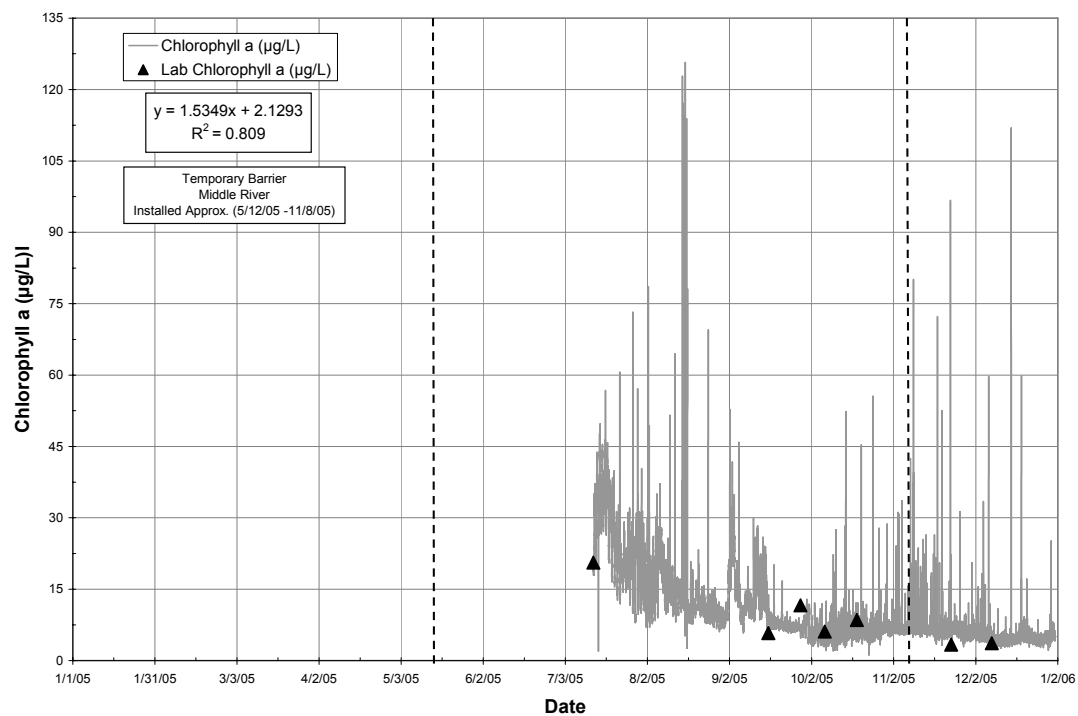


Table 8-14. Statistical summary of 2005 Middle River continuous water quality data: water temperature, dissolved oxygen and pH

Month	Water Temperature (°C)			Dissolved Oxygen (mg/L)			pH		
	UNDINE	HOWARD	TRACY	UNDINE	HOWARD	TRACY	UNDINE	HOWARD	TRACY
Jan. - Max.	11.84	11.46	10.81	8.90	10.48	10.90	8.02	7.85	7.84
Jan. - Avg.	9.55	9.51	9.25	8.09	9.30	8.98	7.76	7.66	7.53
Jan. - Min.	8.27	8.39	8.26	7.11	7.56	5.48	7.56	7.47	7.29
Jan. - S.D.	0.77	0.69	0.55	0.33	0.64	0.50	0.09	0.07	0.11
Feb. - Max.	14.54	14.80	15.27	9.02	10.74	9.57	8.35	7.94	7.96
Feb. - Avg.	12.58	12.70	12.56	7.78	9.59	8.77	7.87	7.75	7.76
Feb. - Min.	9.69	9.48	9.47	6.72	8.54	7.56	7.70	7.47	7.54
Feb. - S.D.	1.11	1.16	1.39	0.42	0.45	0.51	0.06	0.08	0.07
Mar. - Max.	17.57	18.10	19.19	13.97	13.42	12.04	7.99	8.52	8.33
Mar. - Avg.	14.40	14.56	15.17	10.19	10.16	9.52	7.54	7.68	7.78
Mar. - Min.	12.66	12.54	12.68	7.85	8.48	7.51	7.06	7.16	6.92
Mar. - S.D.	1.05	1.22	1.39	0.73	0.97	0.83	0.28	0.24	0.16
Apr. - Max.	16.73	18.16	19.79	10.13	13.41	11.78	8.06	8.25	8.40
Apr. - Avg.	14.52	14.83	15.80	8.33	10.12	9.45	7.68	7.46	7.89
Apr. - Min.	12.52	12.58	12.76	7.07	8.60	7.61	7.37	7.15	7.49
Apr. - S.D.	0.93	1.20	1.51	0.96	0.76	0.91	0.15	0.20	0.21
May - Max.	19.55	20.76	23.70	7.63	14.93	9.71	7.95	8.36	7.85
May - Avg.	16.89	17.37	19.20	6.83	12.78	7.55	7.56	7.61	7.51
May - Min.	14.59	14.44	16.21	6.21	10.85	5.57	7.25	7.26	7.26
May - S.D.	1.16	1.32	1.23	0.35	0.87	0.76	0.16	0.20	0.10
Jun. - Max.	23.53	26.91	27.51	8.16	12.04	9.44	8.16	8.35	7.91
Jun. - Avg.	19.38	20.17	21.56	7.27	8.30	6.89	7.27	7.28	7.39
Jun. - Min.	16.93	17.09	18.09	6.88	5.85	4.06	6.88	7.02	7.13
Jun. - S.D.	1.15	1.68	1.66	0.24	1.01	0.77	0.24	0.25	0.11
Jul. - Max.	27.21	28.29	29.58	15.20	14.26	8.26	9.01	8.87	7.66
Jul. - Avg.	23.79	25.00	25.80	10.54	7.85	5.38	7.90	7.44	7.06
Jul. - Min.	19.69	20.73	21.94	6.16	0.13	0.86	7.31	6.79	6.78
Jul. - S.D.	1.88	1.81	1.51	1.58	2.18	1.16	0.43	0.41	0.19
Aug. - Max.	27.11	27.54	27.97	13.69	10.72	8.37	8.79	8.46	7.48
Aug. - Avg.	24.41	24.98	24.93	9.69	6.38	5.02	8.00	7.51	7.15
Aug. - Min.	21.93	21.66	23.01	7.29	0.22	2.39	7.50	6.91	6.92
Aug. - S.D.	1.17	1.09	1.13	1.36	1.99	1.04	0.30	0.27	0.11
Sep. - Max.	25.30	25.13	25.59	15.97	12.14	9.60	8.96	8.22	7.45
Sep. - Avg.	21.59	21.78	21.46	8.52	7.88	5.56	7.71	7.67	7.10
Sep. - Min.	19.17	19.27	19.24	4.45	5.37	2.05	7.29	7.33	6.88
Sep. - S.D.	1.44	1.37	1.38	1.88	1.11	1.01	0.37	0.14	0.11
Oct. - Max.	23.03	22.79	22.17	10.63	13.92	11.12	8.29	8.72	8.02
Oct. - Avg.	18.26	17.92	18.45	7.99	8.95	7.59	7.70	7.45	7.15
Oct. - Min.	15.05	14.74	15.27	4.37	4.13	4.73	7.37	6.87	6.73
Oct. - S.D.	1.50	1.36	1.24	1.07	1.97	1.17	0.15	0.45	0.31
Nov. - Max.	17.20	16.85	16.86	13.17	12.31	11.11	8.43	8.54	7.90
Nov. - Avg.	13.54	13.48	13.76	9.35	9.89	8.45	7.79	7.99	7.13
Nov. - Min.	9.25	9.57	9.79	7.83	7.94	5.81	7.59	7.48	6.78
Nov. - S.D.	1.80	1.80	1.47	0.99	0.85	1.23	0.12	0.21	0.24
Dec. - Max.	13.25	13.67	12.37	13.03	11.87	11.59	8.13	8.30	7.82
Dec. - Avg.	10.70	10.18	10.49	10.14	9.45	9.49	7.70	7.62	7.41
Dec. - Min.	7.99	7.61	8.30	8.29	7.24	6.00	7.35	7.33	7.08
Dec. - S.D.	1.41	1.75	1.07	0.68	0.71	1.20	0.11	0.21	0.17
2005 - Max.	27.21	28.29	29.58	15.97	14.93	12.04	9.01	8.87	8.40
2005 - Avg.	16.70	16.92	17.40	8.95	9.18	7.58	7.66	7.56	7.32
2005 - Min.	7.99	7.61	8.26	4.37	0.13	0.86	6.88	6.79	6.73
2005 - S.D.	4.92	5.25	5.37	1.52	2.03	1.90	0.31	0.30	0.32

Table 8-15. Statistical summary of 2005 Old River continuous water quality data: water temperature, dissolved oxygen and pH

Month	Water Temperature (°C)			Dissolved Oxygen (mg/L)			pH		
	HEAD	TWA	DMC	HEAD	TWA	DMC	HEAD	TWA	DMC
Jan. - Max.	11.58	11.22	-	11.44	-	-	7.90	7.89	-
Jan. - Avg.	9.77	9.66	-	10.56	-	-	7.62	7.53	-
Jan. - Min.	8.56	8.54	-	9.63	-	-	7.44	7.30	-
Jan. - S.D.	0.79	0.71	-	0.48	-	-	0.11	0.12	-
Feb. - Max.	14.56	14.54	-	11.39	-	-	7.88	8.13	-
Feb. - Avg.	12.77	12.84	-	9.98	-	-	7.73	7.74	-
Feb. - Min.	10.19	10.16	-	8.41	-	-	7.59	7.52	-
Feb. - S.D.	0.99	1.11	-	0.95	-	-	0.07	0.11	-
Mar. - Max.	17.33	17.89	18.62	11.54	16.61	14.23	8.21	9.12	8.70
Mar. - Avg.	14.34	14.87	15.22	9.52	10.94	10.22	7.73	7.99	7.78
Mar. - Min.	12.79	12.67	13.14	7.06	8.54	7.95	7.32	7.49	7.33
Mar. - S.D.	0.99	1.18	1.25	1.25	1.48	1.32	0.19	0.35	0.33
Apr. - Max.	16.52	17.39	19.73	10.95	13.21	12.84	8.11	8.50	8.82
Apr. - Avg.	14.39	15.01	15.50	10.08	10.27	10.64	7.57	7.67	7.94
Apr. - Min.	12.65	12.84	13.20	9.04	8.47	8.67	7.31	7.38	7.44
Apr. - S.D.	0.79	1.06	1.07	0.45	0.91	0.60	0.10	0.20	0.25
May - Max.	19.38	20.41	21.10	11.13	12.14	11.99	-	8.12	8.34
May - Avg.	16.68	17.70	18.19	10.15	10.27	10.32	-	7.57	7.66
May - Min.	14.46	15.42	15.48	8.60	7.95	7.91	-	7.27	7.41
May - S.D.	1.14	1.07	1.22	0.47	0.78	0.80	-	0.16	0.19
Jun. - Max.	22.87	24.08	24.85	9.52	11.38	10.13	7.65	8.14	8.47
Jun. - Avg.	19.22	19.99	20.47	8.37	8.28	7.62	7.24	7.34	7.52
Jun. - Min.	16.78	17.37	16.08	7.51	6.74	5.27	7.02	7.10	7.28
Jun. - S.D.	1.03	1.20	1.02	0.53	0.75	0.74	0.18	0.18	0.18
Jul. - Max.	26.68	27.49	27.16	13.56	13.99	14.78	8.92	8.88	8.37
Jul. - Avg.	23.49	24.44	24.45	9.51	9.09	7.54	7.89	7.75	7.54
Jul. - Min.	19.49	20.51	20.98	6.93	6.70	1.82	7.33	7.26	7.32
Jul. - S.D.	1.79	1.71	1.40	1.30	1.46	2.41	0.40	0.34	0.13
Aug. - Max.	26.96	27.31	26.73	13.78	13.32	10.28	9.00	8.31	8.40
Aug. - Avg.	24.38	24.83	24.43	9.59	7.88	5.57	8.04	7.51	7.45
Aug. - Min.	22.44	22.85	22.63	7.19	3.05	2.65	7.70	7.14	7.05
Aug. - S.D.	0.94	0.97	1.02	1.16	1.66	1.19	0.24	0.14	0.20
Sep. - Max.	26.34	25.71	24.68	15.96	10.42	10.18	8.90	8.52	8.25
Sep. - Avg.	21.63	21.78	21.15	8.18	6.14	6.40	7.65	7.36	7.54
Sep. - Min.	19.41	19.98	19.16	4.77	3.42	2.88	7.16	6.94	7.19
Sep. - S.D.	1.38	1.27	1.21	1.31	1.00	1.27	0.33	0.35	0.20
Oct. - Max.	23.22	22.50	21.88	8.92	14.87	10.76	7.84	8.75	8.46
Oct. - Avg.	18.27	18.84	18.42	7.74	7.44	6.78	7.59	7.64	7.69
Oct. - Min.	15.38	16.19	16.43	5.11	3.61	3.25	7.23	7.02	7.31
Oct. - S.D.	1.41	1.20	0.98	0.61	1.68	1.33	0.10	0.30	0.27
Nov. - Max.	16.97	16.87	17.10	9.76	9.72	10.34	7.80	7.98	8.04
Nov. - Avg.	14.57	13.93	14.19	8.90	7.92	7.77	7.73	7.77	7.74
Nov. - Min.	12.74	10.31	10.63	8.13	4.12	2.70	7.50	7.40	7.43
Nov. - S.D.	0.69	1.65	1.42	0.29	1.08	1.37	0.05	0.09	0.10
Dec. - Max.	12.76	13.31	13.29	11.10	10.52	11.30	7.98	7.96	8.00
Dec. - Avg.	10.46	10.84	10.93	10.42	8.90	9.35	7.80	7.71	7.78
Dec. - Min.	8.88	8.72	8.59	8.38	6.20	6.03	7.62	7.42	7.47
Dec. - S.D.	0.97	1.30	1.21	0.41	0.88	0.94	0.10	0.12	0.10
2005 - Max.	26.96	27.49	27.16	15.96	16.61	14.78	9.00	9.12	8.82
2005 - Avg.	16.99	17.14	18.43	9.38	8.66	7.92	7.64	7.60	7.64
2005 - Min.	8.56	8.54	8.59	4.77	3.05	1.82	7.02	6.94	7.05
2005 - S.D.	4.73	4.97	4.36	1.25	1.84	2.09	0.30	0.29	0.26

Table 8-16. Statistical summary of 2005 Middle River continuous water quality data: specific conductance, turbidity and chlorophyll a

Month	Specific Conductance ($\mu\text{S/cm}$)			Turbidity (NTU)			Chlorophyll a ($\mu\text{g/L}$)		
	UNDINE	HOWARD	TRACY	UNDINE	HOWARD	TRACY	UNDINE	HOWARD	TRACY
Jan. - Max.	1464.0	1664.0	1443.0	120.5	194.7	78.3	-	-	-
Jan. - Avg.	600.6	889.8	811.4	49.2	37.1	22.1	-	-	-
Jan. - Min.	277.0	378.0	370.0	14.8	10.1	3.3	-	-	-
Jan. - S.D.	206.9	307.5	216.8	23.4	21.5	10.0	-	-	-
Feb. - Max.	1216.0	1387.0	1537.0	76.9	41.9	31.1	-	-	-
Feb. - Avg.	657.4	840.8	865.3	29.3	21.2	11.4	-	-	-
Feb. - Min.	434.0	480.0	445.0	8.7	10.6	3.7	-	-	-
Feb. - S.D.	124.7	199.6	215.5	15.5	7.0	4.0	-	-	-
Mar. - Max.	672.0	893.0	874.0	139.6	117.1	96.6	-	-	-
Mar. - Avg.	506.3	593.2	656.2	38.2	27.7	17.7	-	-	-
Mar. - Min.	246.0	271.0	299.0	9.5	9.1	3.4	-	-	-
Mar. - S.D.	122.9	138.6	132.0	21.0	15.3	13.5	-	-	-
Apr. - Max.	342.0	471.0	483.0	45.7	46.5	38.0	-	-	-
Apr. - Avg.	286.3	327.2	369.7	27.6	23.6	12.9	-	-	-
Apr. - Min.	244.0	262.0	280.0	14.7	6.4	3.7	-	-	-
Apr. - S.D.	21.5	33.2	40.8	5.3	6.5	4.3	-	-	-
May - Max.	333.0	539.0	431.0	61.2	115.9	26.7	-	-	-
May - Avg.	188.5	214.5	288.7	31.2	23.0	13.4	-	-	-
May - Min.	100.0	108.0	130.0	10.9	14.4	6.6	-	-	-
May - S.D.	59.2	72.9	88.3	7.3	5.9	2.9	-	-	-
Jun. - Max.	384.0	719.0	473.0	85.3	86.6	69.2	-	-	-
Jun. - Avg.	212.0	249.6	294.5	21.5	26.9	17.8	-	-	-
Jun. - Min.	112.0	116.0	166.0	1.5	15.3	9.8	-	-	-
Jun. - S.D.	75.9	111.7	87.5	7.9	2.4	4.4	-	-	-
Jul. - Max.	565.0	1021.0	505.0	102.4	54.5	86.9	-	73.2	-
Jul. - Avg.	408.3	464.6	312.9	25.4	30.5	14.6	-	25.5	-
Jul. - Min.	218.0	240.0	217.7	8.6	3.1	4.8	-	2.0	-
Jul. - S.D.	106.7	111.4	44.1	5.6	7.6	5.0	-	8.1	-
Aug. - Max.	648.0	968.2	568.8	77.0	172.9	145.4	-	125.2	-
Aug. - Avg.	498.8	558.0	358.9	25.3	27.8	9.5	-	14.2	-
Aug. - Min.	418.4	455.7	226.7	11.1	2.0	3.1	-	2.6	-
Aug. - S.D.	36.2	52.8	99.7	6.1	17.0	4.1	-	7.7	-
Sep. - Max.	713.0	1142.8	721.0	134.7	70.4	143.2	-	52.8	-
Sep. - Avg.	542.0	603.3	520.5	17.0	13.6	5.9	-	11.3	-
Sep. - Min.	430.0	441.2	288.2	7.0	5.0	0.3	-	4.7	-
Sep. - S.D.	86.6	119.5	113.1	9.1	4.3	6.3	-	5.4	-
Oct. - Max.	695.2	1013.9	571.1	190.9	26.3	20.6	-	55.5	-
Oct. - Avg.	540.8	577.9	417.8	14.0	4.7	4.5	-	6.5	-
Oct. - Min.	426.8	428.5	306.9	3.4	0.1	1.5	-	1.2	-
Oct. - S.D.	66.9	91.6	76.9	17.0	3.2	1.3	-	2.4	-
Nov. - Max.	869.0	1114.3	750.4	97.1	32.7	39.0	-	96.7	-
Nov. - Avg.	736.6	778.7	557.8	9.4	3.3	4.7	-	6.8	-
Nov. - Min.	527.1	552.5	373.3	0.9	0.2	0.7	-	2.9	-
Nov. - S.D.	81.4	109.0	94.2	6.2	2.1	2.8	-	3.5	-
Dec. - Max.	901.1	975.6	731.3	139.0	103.7	174.6	-	111.9	-
Dec. - Avg.	663.8	706.8	519.3	12.0	4.0	5.4	-	5.0	-
Dec. - Min.	208.1	232.0	339.8	2.4	0.2	0.9	-	2.1	-
Dec. - S.D.	184.9	182.5	76.2	9.4	4.0	4.7	-	2.8	-
2005 - Max.	1464.0	1664.0	1537.0	190.9	194.7	174.6	-	125.2	-
2005 - Avg.	483.5	565.3	495.8	25.7	20.3	11.6	-	10.6	-
2005 - Min.	100.0	108.0	130.0	0.9	0.1	0.3	-	1.2	-
2005 - S.D.	203.5	256.6	221.7	17.0	14.9	8.5	-	8.05	-

Table 8-17. Statistical summary of 2005 Old River continuous water quality data: specific conductance, turbidity and chlorophyll a

Month	Specific Conductance ($\mu\text{S}/\text{cm}$)			Turbidity (NTU)			Chlorophyll a ($\mu\text{g}/\text{L}$)		
	HEAD	TWA	DMC	HEAD	TWA	DMC	HEAD	TWA	DMC
Jan. - Max.	993.0	1312.0	-	134.3	73.2	-	-	-	-
Jan. - Avg.	570.7	697.5	-	75.6	35.5	-	-	-	-
Jan. - Min.	268.0	305.0	-	15.1	17.0	-	-	-	-
Jan. - S.D.	173.6	202.9	-	20.9	12.7	-	-	-	-
Feb. - Max.	959.0	1214.0	-	128.1	46.5	-	-	-	-
Feb. - Avg.	653.2	779.5	-	42.1	23.5	-	-	-	-
Feb. - Min.	420.0	449.0	-	18.0	13.2	-	-	-	-
Feb. - S.D.	113.3	163.1	-	18.3	7.5	-	-	-	-
Mar. - Max.	790.0	1269.0	914.0	89.9	160.5	197.3	-	-	-
Mar. - Avg.	508.9	736.3	584.8	29.4	23.9	16.2	-	-	-
Mar. - Min.	241.0	388.0	266.0	12.6	2.5	4.0	-	-	-
Mar. - S.D.	124.2	162.4	160.8	15.0	13.1	13.5	-	-	-
Apr. - Max.	499.0	886.0	764.0	33.5	38.1	67.7	-	-	-
Apr. - Avg.	296.4	390.6	426.0	16.9	15.7	24.6	-	-	-
Apr. - Min.	243.0	283.0	262.0	1.2	4.5	10.4	-	-	-
Apr. - S.D.	34.3	96.0	93.5	4.0	6.0	7.7	-	-	-
May - Max.	402.0	609.0	437.0	86.0	96.8	69.2	-	-	-
May - Avg.	196.9	261.9	262.3	26.0	20.8	19.2	-	-	-
May - Min.	101.0	120.0	127.0	14.2	10.6	10.8	-	-	-
May - S.D.	58.5	91.0	72.6	6.5	4.7	4.2	-	-	-
Jun. - Max.	426.0	577.0	466.0	170.2	76.4	49.9	-	-	-
Jun. - Avg.	209.9	271.2	298.1	35.0	39.8	25.5	-	-	-
Jun. - Min.	105.0	128.0	148.0	16.4	11.4	9.2	-	-	-
Jun. - S.D.	91.4	93.4	79.8	16.3	11.3	7.7	-	-	-
Jul. - Max.	684.0	694.0	672.0	123.1	69.7	57.1	194.8	185.7	-
Jul. - Avg.	478.5	493.3	493.4	33.2	28.7	26.6	53.5	51.5	-
Jul. - Min.	232.0	237.0	195.0	14.1	15.6	4.3	13.4	18.1	-
Jul. - S.D.	146.0	115.3	116.8	12.8	10.4	8.0	20.9	23.6	-
Aug. - Max.	640.1	704.3	734.3	158.9	107.9	162.7	81.6	329.1	-
Aug. - Avg.	515.3	575.1	653.7	27.4	23.0	15.1	41.9	26.6	-
Aug. - Min.	436.9	488.5	310.8	13.7	8.8	6.9	15.4	-2.9	-
Aug. - S.D.	24.5	34.3	47.4	6.7	6.4	5.3	12.8	34.1	-
Sep. - Max.	752.5	868.5	917.6	91.7	40.6	32.1	96.1	83.2	-
Sep. - Avg.	580.8	669.8	763.1	18.1	13.3	10.6	26.1	16.4	-
Sep. - Min.	462.9	494.7	557.4	8.1	5.7	2.1	3.8	-2.1	-
Sep. - S.D.	78.9	82.9	83.8	4.6	3.2	4.3	20.8	13.5	-
Oct. - Max.	763.8	1070.0	1187.3	145.7	39.6	57.0	18.7	166.4	-
Oct. - Avg.	554.9	853.1	831.2	19.1	12.0	8.3	6.3	33.5	-
Oct. - Min.	429.7	567.5	353.6	11.0	6.4	2.1	-0.8	0.5	-
Oct. - S.D.	70.6	119.0	202.1	6.7	1.8	2.9	2.5	23.9	-
Nov. - Max.	868.3	1410.2	1193.7	67.9	46.0	138.7	48.2	25.6	-
Nov. - Avg.	739.4	858.0	783.6	18.1	15.5	14.1	3.9	5.4	-
Nov. - Min.	587.3	707.5	420.3	9.4	5.6	-1.2	-1.2	-3.9	-
Nov. - S.D.	82.4	109.4	196.1	5.1	5.5	11.8	2.1	4.4	-
Dec. - Max.	862.5	1117.7	1167.0	137.2	46.0	185.7	33.9	47.2	-
Dec. - Avg.	701.6	731.2	742.9	24.7	14.6	11.4	6.9	7.3	-
Dec. - Min.	179.7	189.0	236.4	8.8	4.0	-1.8	-0.8	-4.7	-
Dec. - S.D.	180.0	205.0	212.5	14.0	5.6	14.9	3.6	5.8	-
2005 - Max.	993.0	1410.2	1193.7	170.2	160.5	197.3	194.8	329.1	-
2005 - Avg.	485.5	616.7	583.3	28.7	22.2	16.6	23.6	22.9	-
2005 - Min.	101.0	120.0	127.0	1.2	2.5	-1.8	-1.2	-4.7	-
2005 - S.D.	197.7	241.6	241.7	17.7	11.9	10.7	23.2	25.8	-

Figure 8-24. 2005 Maximums, averages and minimums for water temperature at the Middle River South Delta continuous monitoring sites

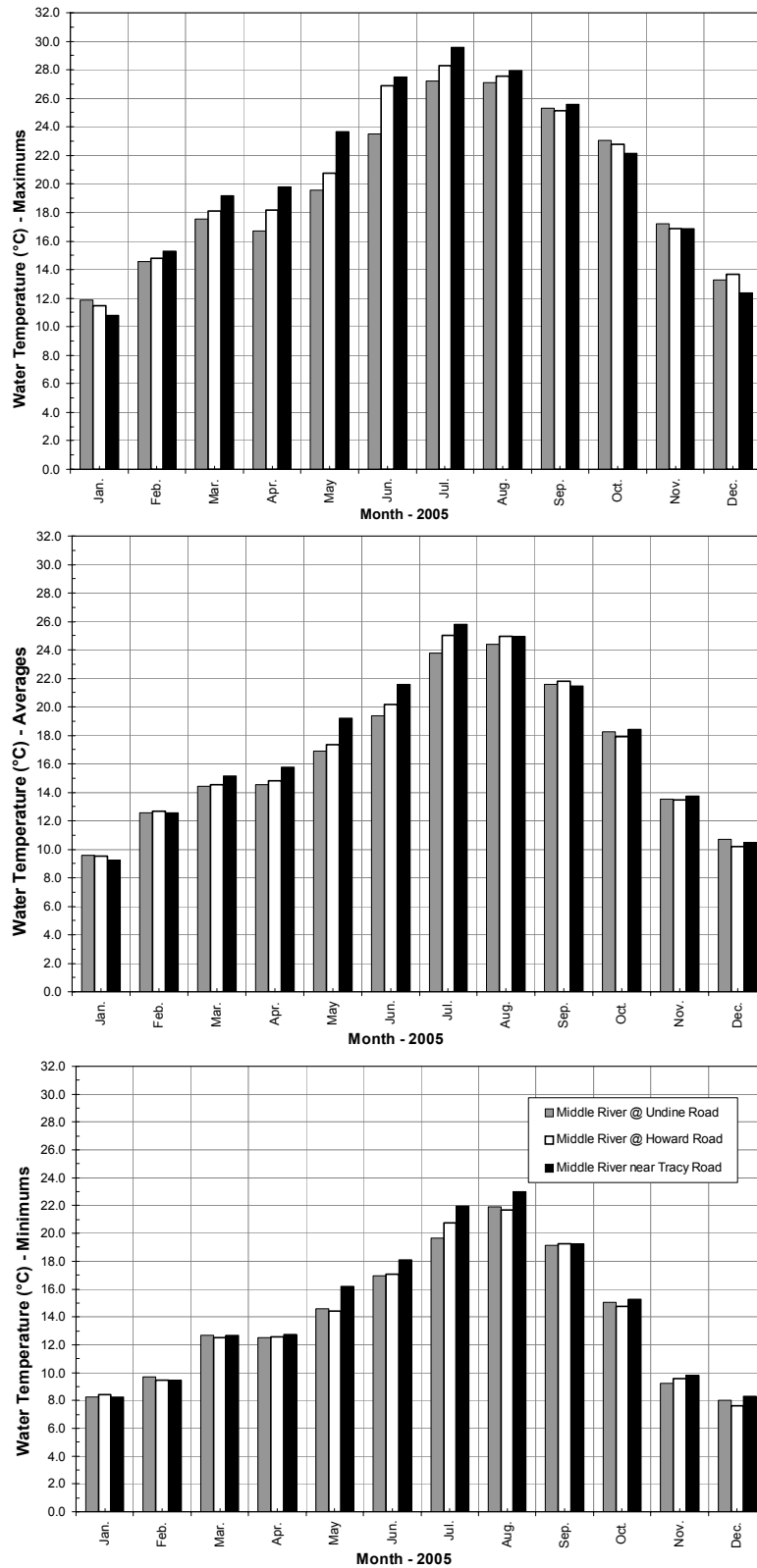


Figure 8-25. 2005 Maximums, averages and minimums for water temperature at the Old River South Delta continuous monitoring sites

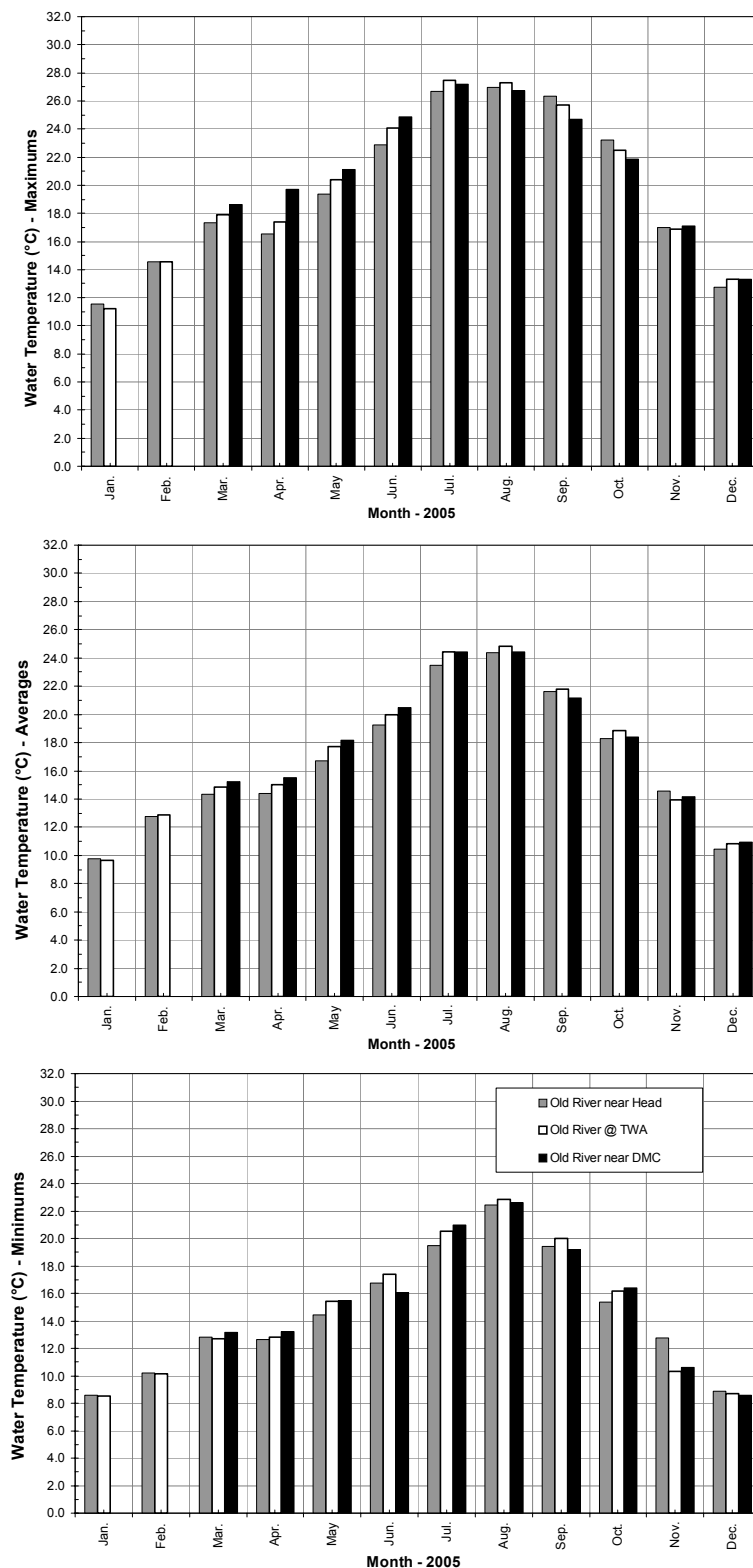


Figure 8-26. 2005 Maximums, averages and minimums for dissolved oxygen at the Middle River South Delta continuous monitoring sites

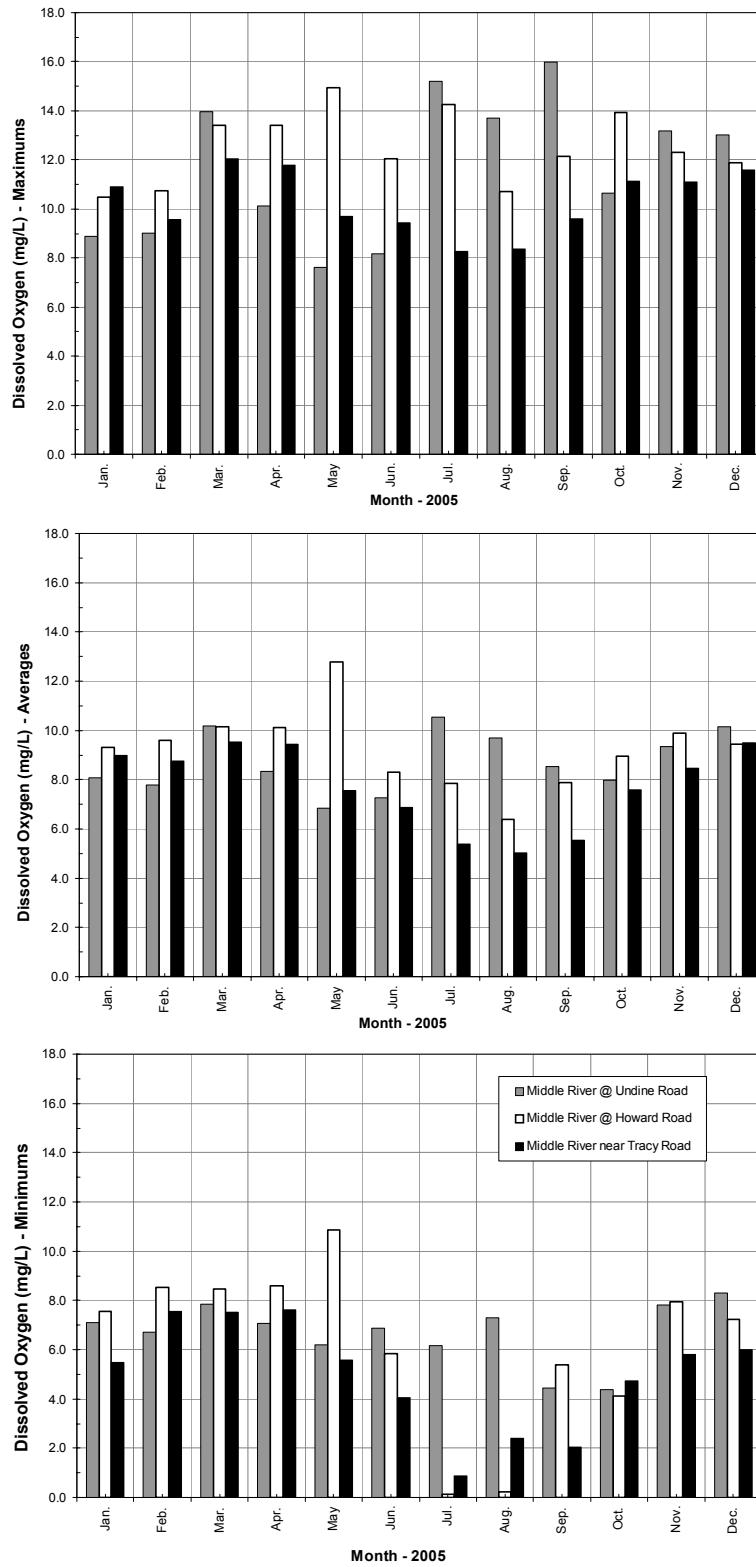


Figure 8-27. 2005 Maximums, averages and minimums for dissolved oxygen at the Old River South Delta continuous monitoring sites

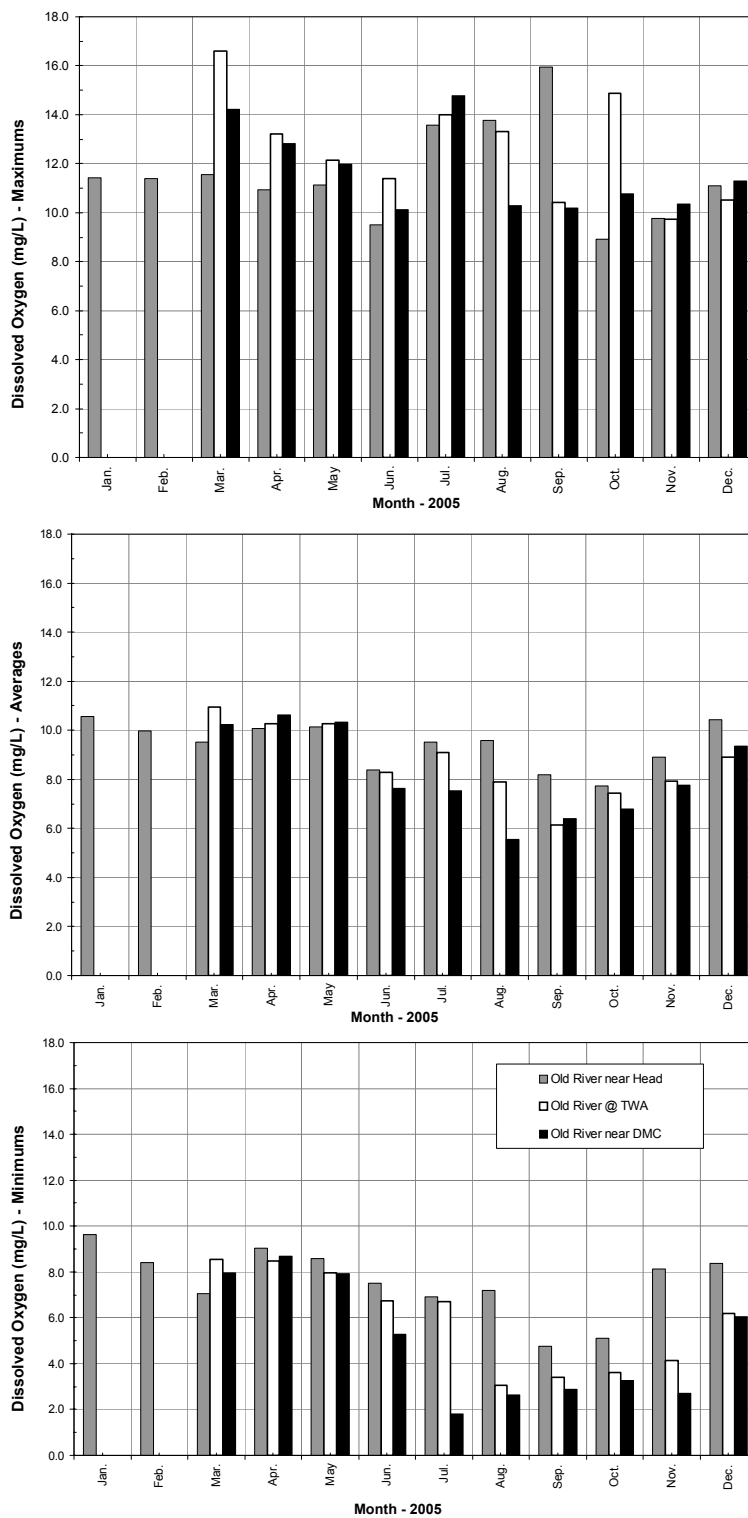


Figure 8-28. 2005 Maximums, averages and minimums for pH at the Middle River South Delta continuous monitoring sites

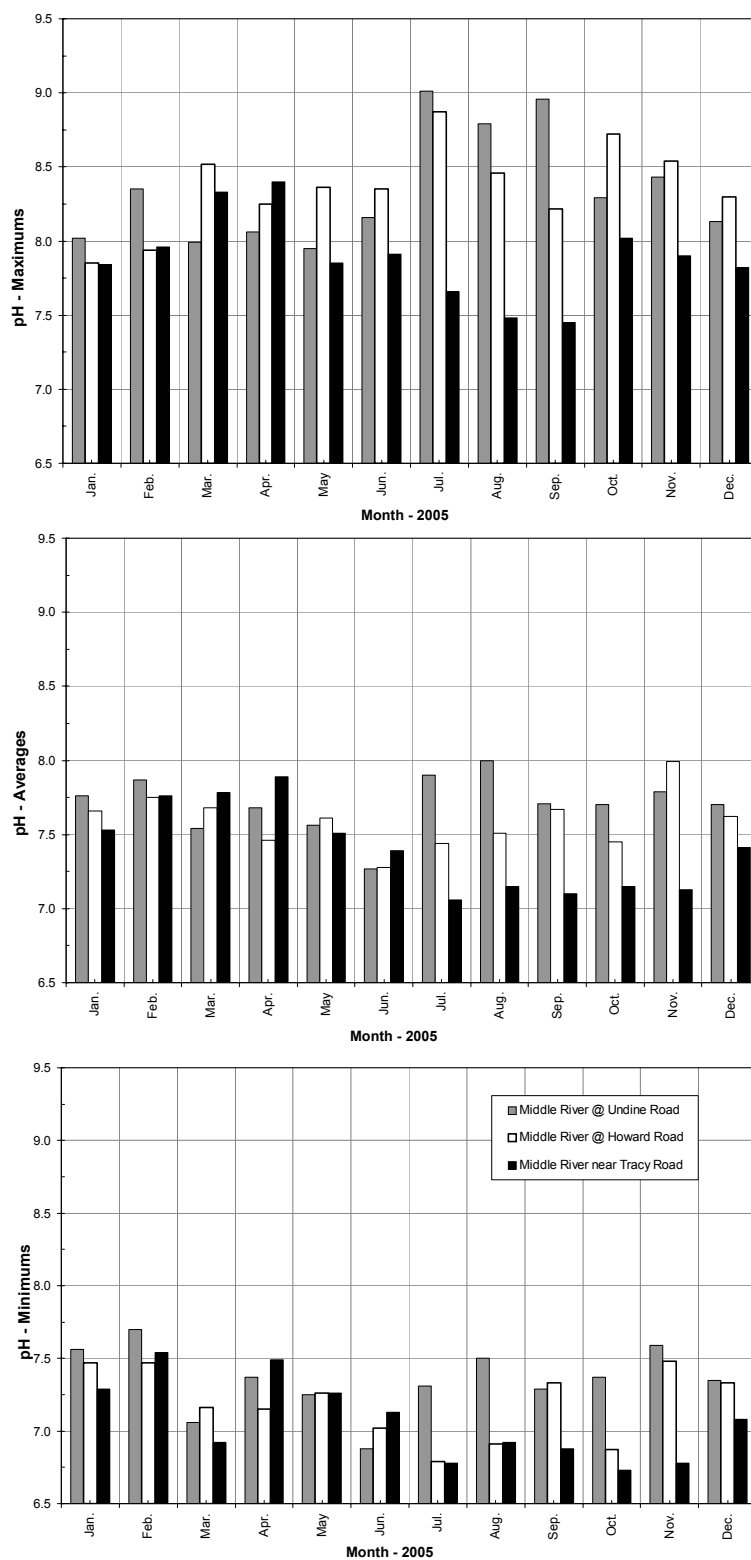


Figure 8-29. 2005 Maximums, averages and minimums for pH at the Old River South Delta continuous monitoring sites

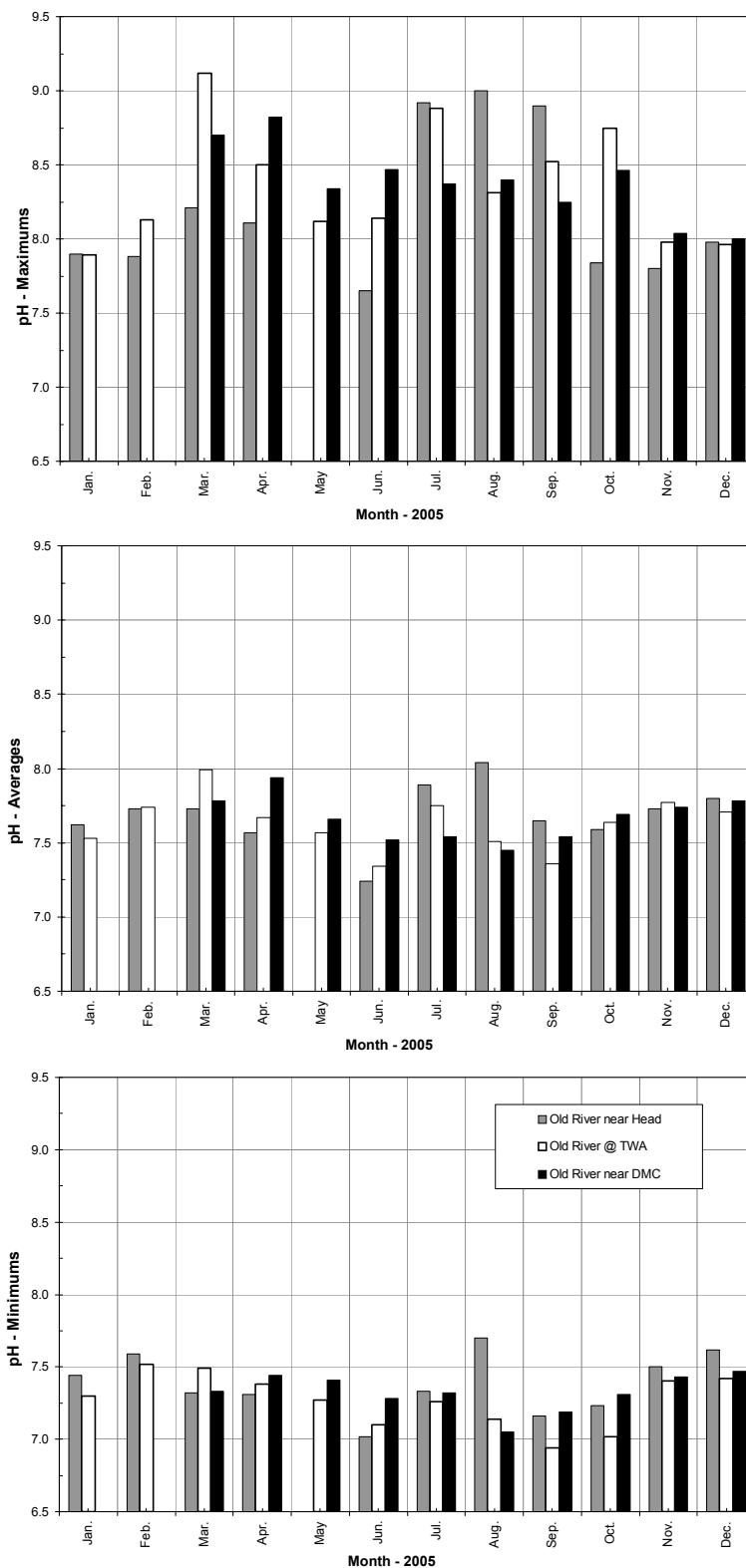


Figure 8-30. 2005 Maximums, averages and minimums of specific conductance at the Middle River South Delta continuous monitoring sites

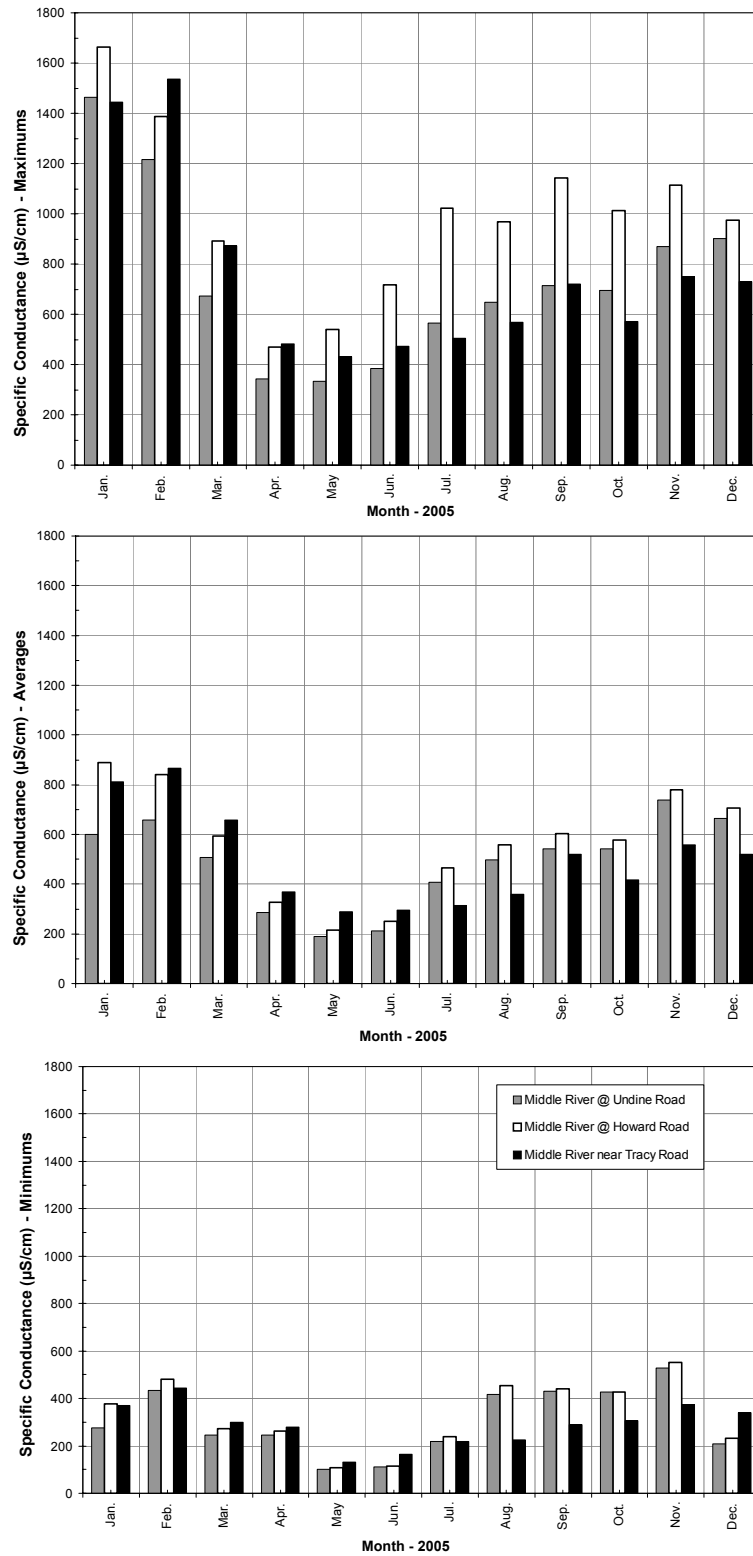


Figure 8-31. 2005 Maximums, averages and minimums for specific conductance at the Old River South Delta continuous monitoring sites

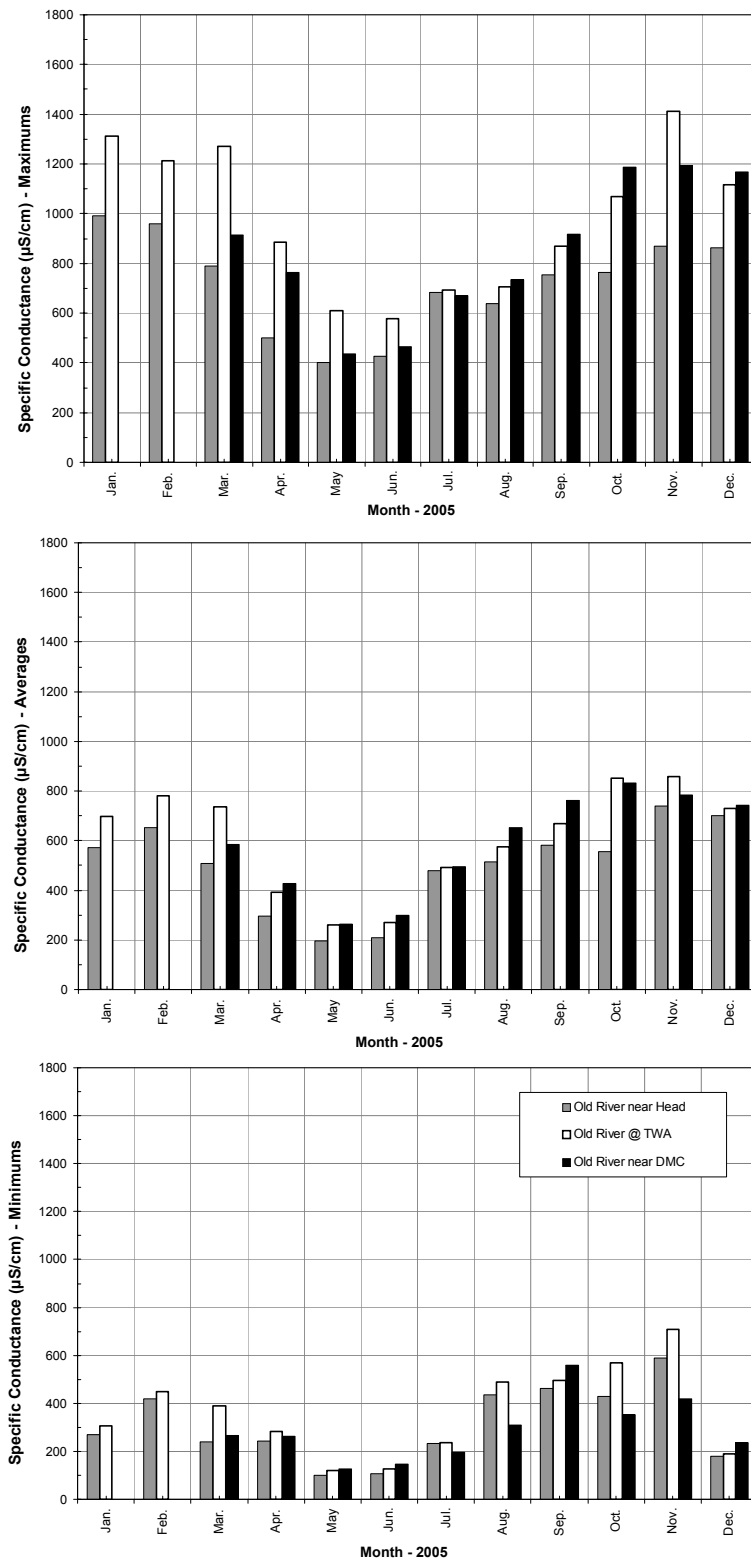


Figure 8-32. 2005 Maximums, averages and minimums for turbidity at the Middle River South Delta continuous monitoring sites

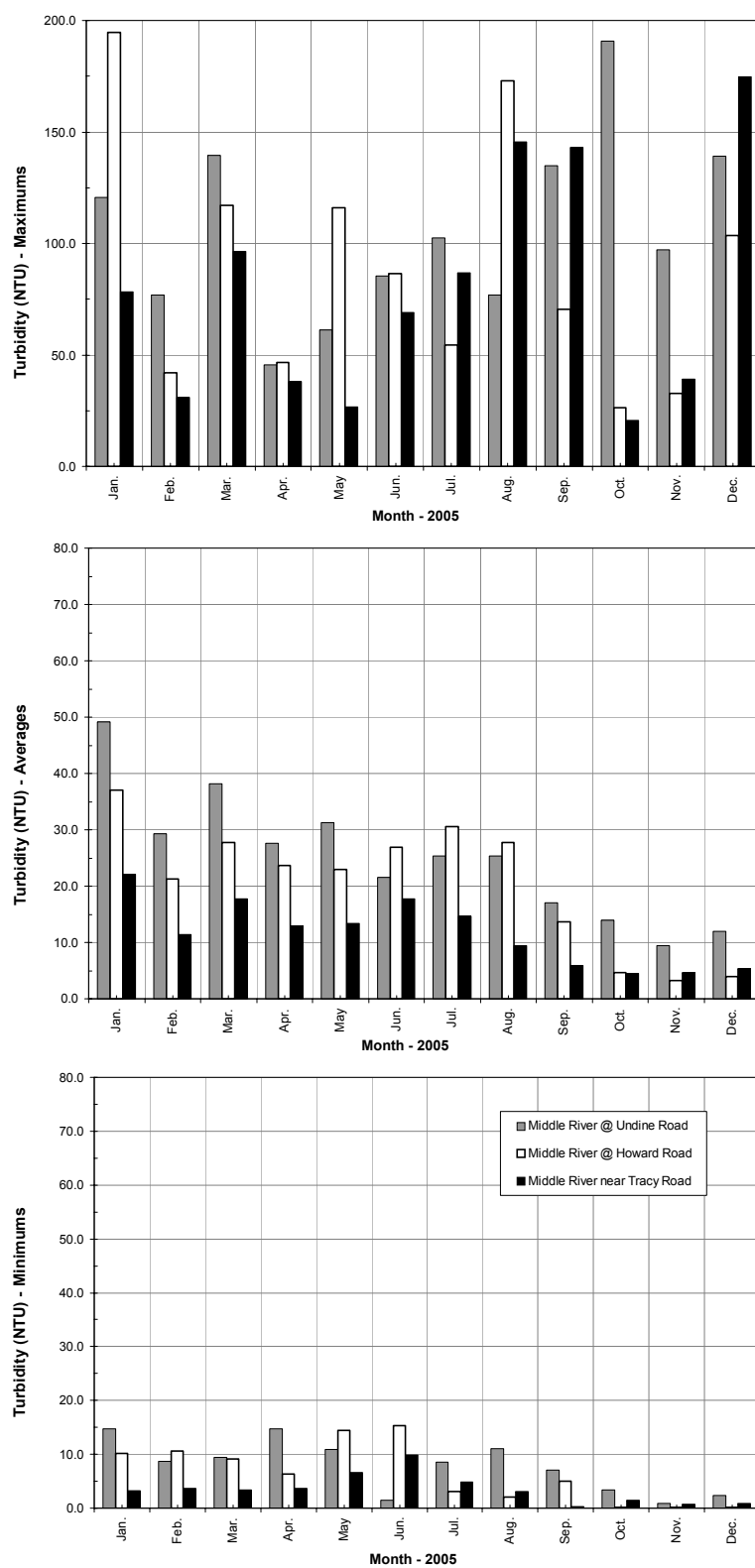


Figure 8-33. 2005 Maximums, averages and minimums for turbidity at the Old River South Delta continuous monitoring sites

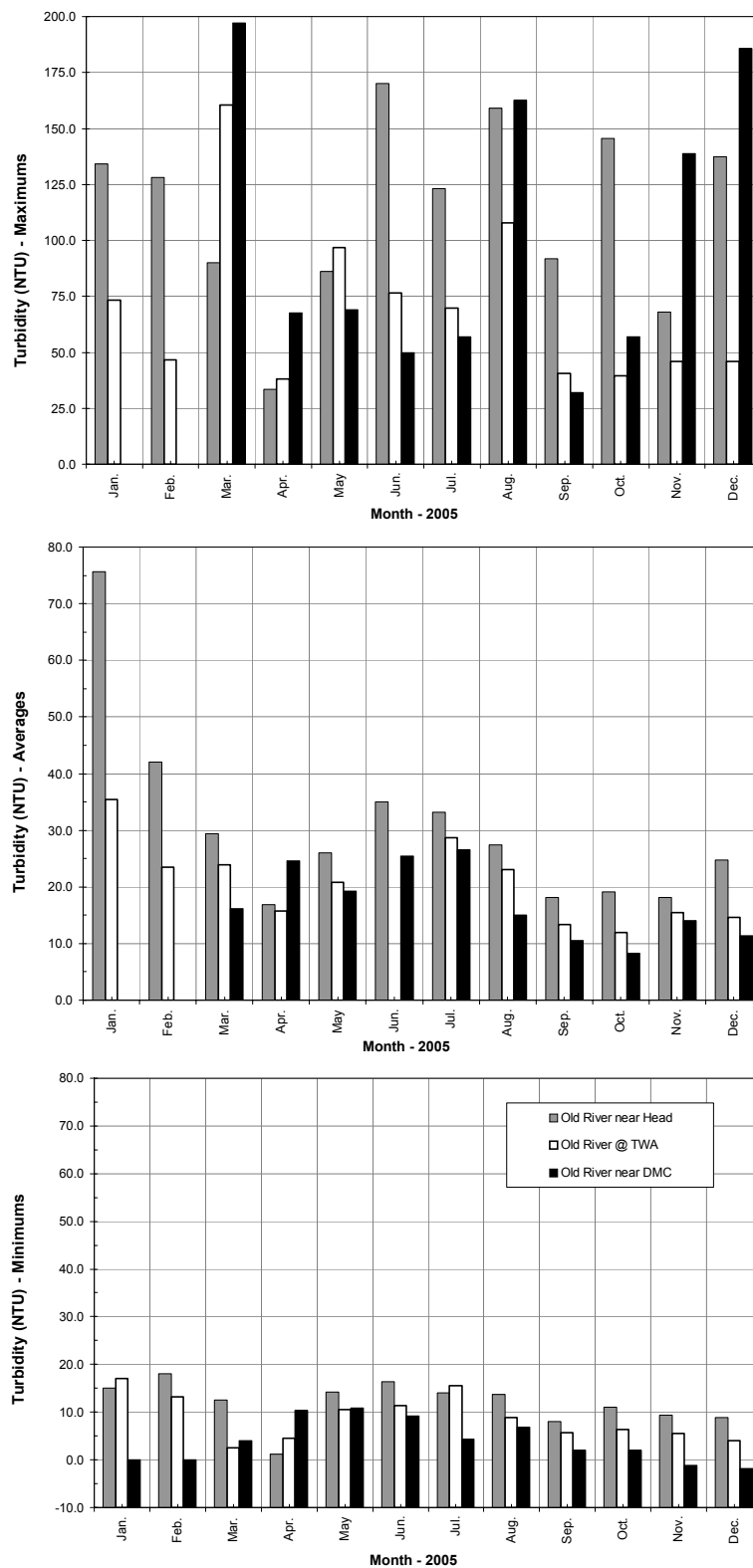
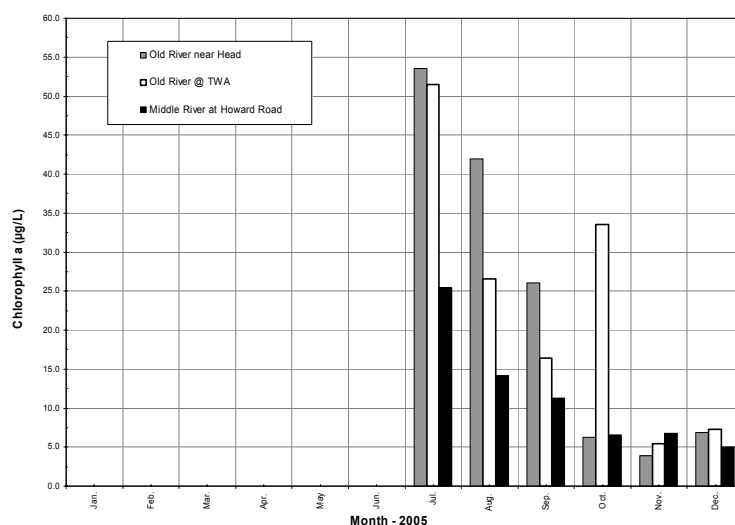


Figure 8-34. 2005 Average chlorophyll *a* concentrations at three South Delta monitoring locations

Dissolved oxygen concentrations were lowest during the summer and early fall at the Middle River near Tracy Road and Old River near DMC sites, likely, due to warm water temperatures, low San Joaquin River flows, low primary productivity as indicated by chlorophyll *a* concentrations, and high biochemical oxygen demand. At Tracy Road and DMC, there were a combined 5,675 instances where DO concentrations were less than 5 mg/L. In contrast, there were only 75 readings below 5 mg/L at the furthest upstream sites, Old River near Head and Middle River at Undine Road. High summer DO concentrations at these sites are likely due to algal photosynthesis that resulted in supersaturated conditions. Overall, mean DO values in 2005 ranged from 7.58 mg/L at Tracy Road to 9.38 mg/L at Head. Refer to Figures 8-26 and 8-27 and Tables 8-14 and 8-15.

pH values > 9.0 were recorded at Middle River at Undine Road and Old River at TWA in July and March, respectively. Algal blooms at the upstream monitoring locations could have contributed to the higher pH values. Mean pH values ranged from 7.32 at Tracy Road to 7.66 at Undine Road. See Figures 8-28 and 8-29 and Tables 8-14 and 8-15.

Old River and Middle River specific conductance values were lowest from April through June, likely due to increased San Joaquin River flows past Vernalis and decreases in CVP and SWP exports. Conductivity values in Middle River were highest in January and February, likely at a result of lower San Joaquin River flows and higher conductance values at Vernalis, CVP and SWP exports, and runoff. Old River conductance values were highest during the late summer and fall, likely as a result of low San Joaquin River flows and higher conductance values at Vernalis, CVP and SWP exports, and agricultural pumping and return flows. In both Middle River and Old River, the monitoring stations between the upstream and downstream sites had the highest specific conductance values. This would seem to suggest that localized influences such as agricultural pumping and return flows are influencing specific conductance in these areas. Large daily fluctuations in specific conductance, especially while the barriers are not operational, appear to indicate that tidal influences affect conductivity at the downstream sites (Tracy Road and DMC). The upstream sites (Head and Undine Road) appear to be primarily influenced by Vernalis conductance values. In 2005, mean specific conductance values ranged from 483.5 µS/cm at Undine Road to 616.7 µS/cm at TWA. See Figures 8-30 and 8-31 and Tables 8-16 and 8-17.

In general, turbidity at all six sites was lower during fall and higher during the winter and summer. Turbidity readings during the summer could have been higher, partially, because of increased primary productivity (algal biomass), low San Joaquin River flows and agricultural pumping and return flows. Winter storms and runoff resulted in high turbidity readings during the winter, especially in January. The furthest sites downstream on both Middle River and Old River had the lowest turbidity readings for most of the year. High water clarity at these sites during the late spring through early fall may be attributed in part to lower algal biomass (lower chlorophyll *a* concentrations). The Middle River near Tracy Road site had the highest average water clarity (least turbid) during the 2005 sampling period. Turbidity values near Tracy Road averaged 11.6 NTU, about 5 NTU lower than at any other site. Mean turbidity readings at the other five sites ranged from 16.6 NTU at DMC to 28.7 NTU at Head. Figures 8-32 and 8-33 and Tables 8-16 and 8-17 shows statistics of the turbidity data recorded at each of the six South Delta continuous monitoring sites.

Warm water temperatures and low San Joaquin River flows during the summer through early fall contributed to high primary productivity at three South Delta locations. Figure 8-34 and Tables 8-16 and 8-17 shows statistics of the chlorophyll *a* data. Old River near Head had the highest chlorophyll *a* concentrations from July through September with values ranging from 26.1 µg/L to 53.5 µg/L. Algal blooms and high primary productivity from the late spring through early fall may contribute to high turbidity values and supersaturated dissolved oxygen concentrations. For example, at Old River near Head, the mean turbidity value in July was 33.2 NTU and the mean DO saturation was 113%, with a maximum of 169%. Mean chlorophyll *a* concentrations were lowest in November and December at all three stations when water temperatures were low.

Recommendations

Expanding the continuous monitoring network to include a few control stations on the downstream side of the barriers would greatly improve the baseline data in the vicinity of the barriers. These stations would measure the same water quality parameters that are already being measured upstream of the barriers. Data generated from these sites could be compared with data generated from sites behind the barriers to assess upstream water quality changes. A possible location to start this expansion would be to place a continuous monitoring station just downstream of the Old River Barrier near DMC, as this location is proximate to an existing installation just upstream of the barrier. If two sites were to be selected, a monitoring site could be located just downstream of the Middle River barrier.

In addition, the next step in developing a greater understanding of South Delta water quality would be to expand the current continuous monitoring network to include Grant Line Canal. Adding sites within Grant Line Canal and Doughty Cut could provide more insight as to potential water quality degradation in Grant Line Canal. Continuous monitoring would complement Central District's discrete water quality sampling program in this area. Again, it would be prudent to install at least two sites, one upstream and one downstream of the GLC barrier to assess potential water quality impacts in the general vicinity of the barrier.

Depth profiling of dissolved oxygen during the summer months at various South Delta locations would be a useful means of determining differences in surface and bottom dissolved oxygen concentrations. Profiling may also help locate dissolved oxygen sinks, where further sampling may be needed to identify causes of degradation. Biochemical oxygen demand (BOD) sampling should be done at all six continuous monitoring sites during the spring, summer and early fall to determine the effect of microorganisms on dissolved oxygen.

Chapter 9. Hydrologic Modeling

This chapter describes the details of the simulation of historical 2005 Delta hydrodynamic conditions as requested by the Temporary Barriers and Lower San Joaquin Section in DWR's Bay-Delta Office. The period of simulation is from January 1, 2005 to December 31, 2005.

To simulate the hydrodynamics, the Delta Modeling Section used DSM2-Hydro which is a one-dimensional open channel unsteady flow model based on a four-point finite difference solution of equations of momentum and continuity. The solution scheme has proven to be stable. The model network extends north to Sacramento River at I street, south to San Joaquin River at Vernalis, and west to Martinez where a 15-minute time history of stage input governs how the tide signal propagates into the Delta.

Boundary conditions

Flow and stage information required at model boundaries were downloaded from the IEP web site (www.iep.water.ca.gov) and from the California Data Exchange Center web site (cdec.water.ca.gov). The IEP database includes data collected by various agencies, including DWR and USGS. When duplicate data from more than one agency was available, they were assigned a priority order. As the first option, DSM2 uses data ranked at the highest priority, and then proceeds to those of lower priority if necessary. Priority was assigned based on data availability, quality of the data, and past experience. Input data, visually examined using plotting routines, was occasionally missing. In most cases, alternate sources of data filled any gaps.

Resulting key boundary conditions for 2005 are shown in Figures 9-1 through 9-5.

Figure 9-1. Daily average historical inflow from the Sacramento River, 2005

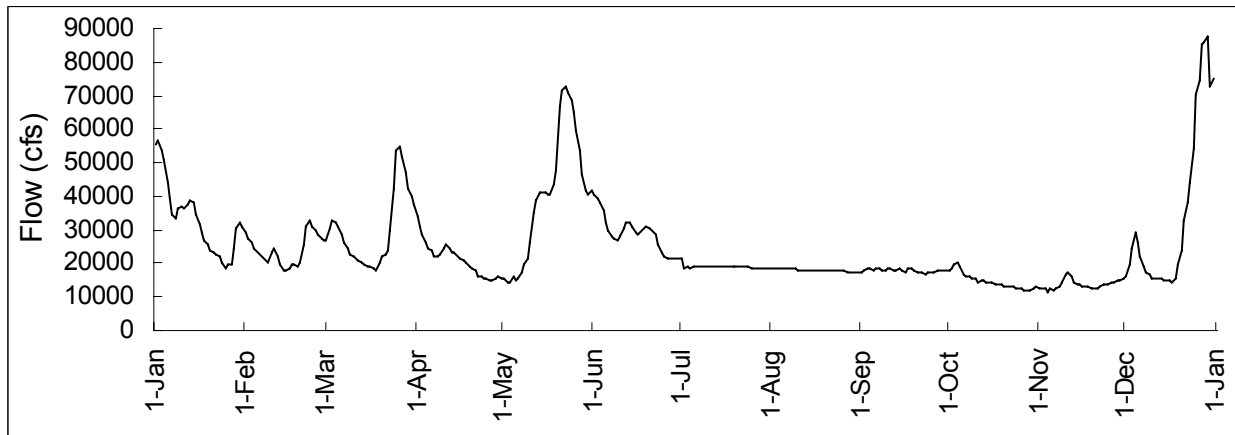


Figure 9-2. Daily average historical inflow from the Yolo Bypass, 2005

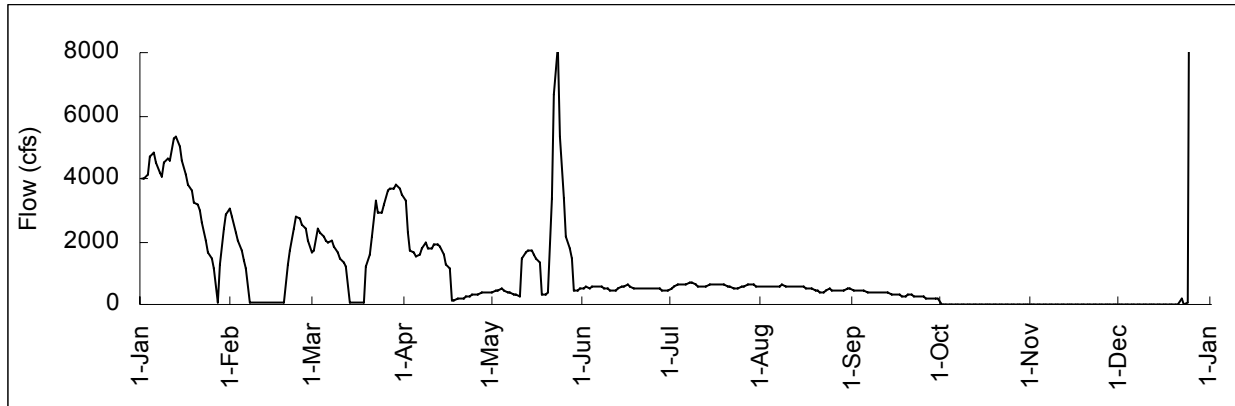


Figure 9-3. Daily average historical inflow from the San Joaquin River, 2005

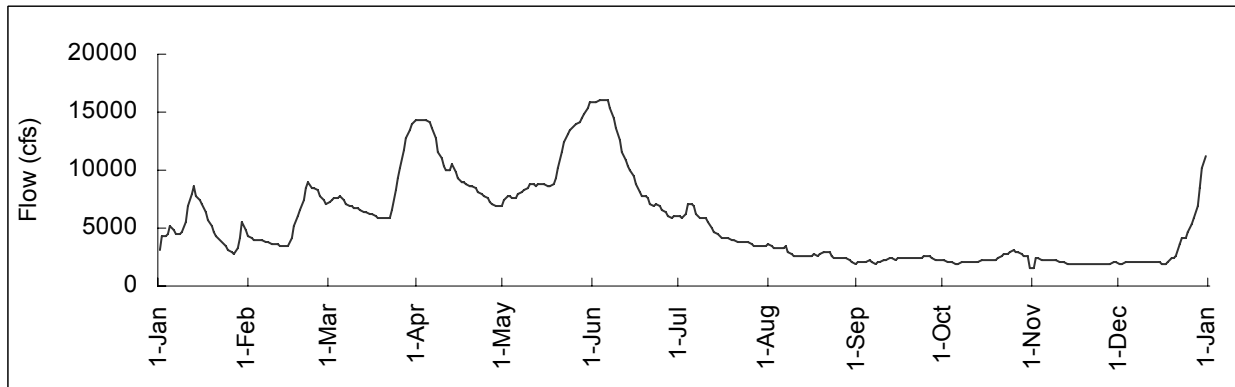


Figure 9-4. Daily average historical pumping at Banks and Delta Pumping plants, 2005

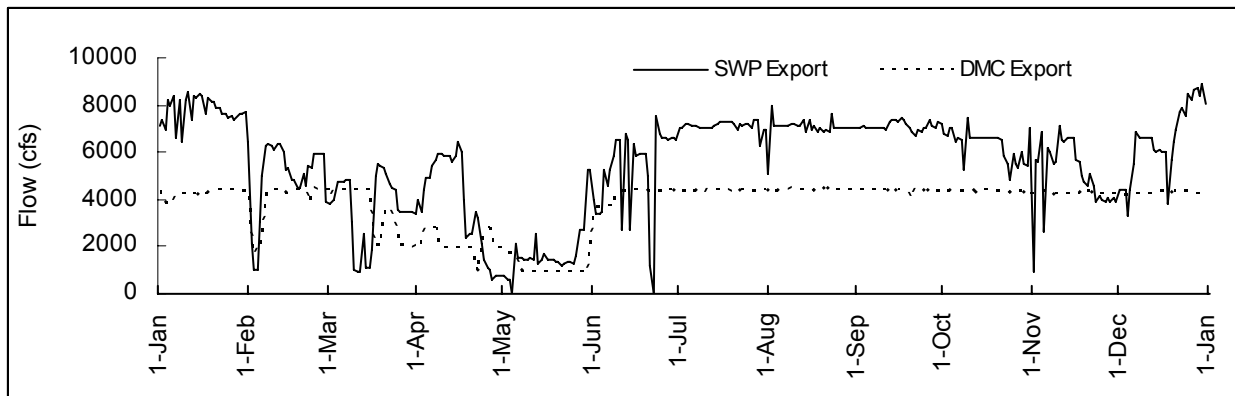
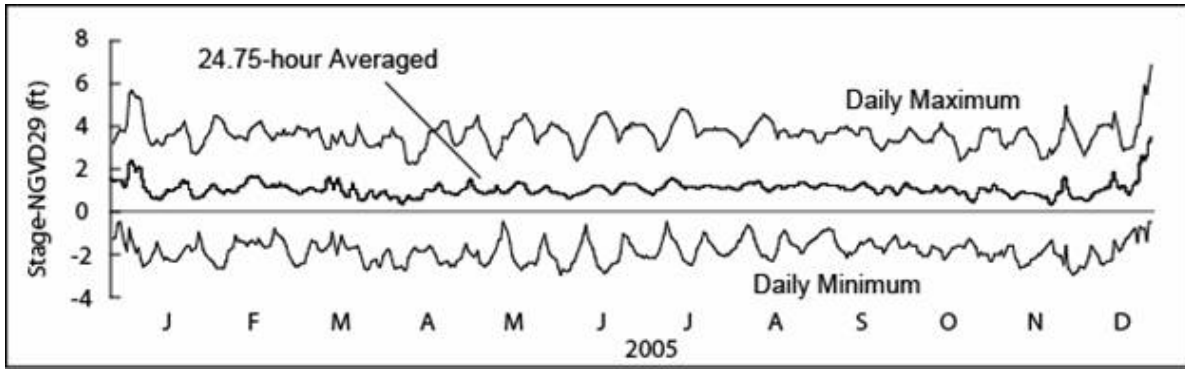


Figure 9-5. Daily maximum, minimum, and 24.75 hour running average of the historical stage at Martinez, 2005



Consumptive use

The Delta Island Consumptive Use (DICU) model provided an estimate of the amount of water diverted from and returned to Delta channels due to agricultural activities. Input to DICU model includes precipitation, pan evaporation data, and water year types. The water year type determines which of two possible cropping patterns in the Delta is assumed, which in turn contributes to the estimation of agricultural water needs.

Delta Structures

All three temporary agricultural barriers were installed in 2005 in addition to the fall barrier at the head of Old River. The spring barrier at the head of Old River was not installed. While installation and removal of the temporary barriers may have taken days or weeks, the DSM2 simulation timed the actual installation and removal to effective dates and times, as inferred from 15-minute observed water levels. Table 9-1 describes the historical and DSM2-assumed operation of all the South Delta Barriers.

Table 9-1. Historical and DSM2-assumed south Delta barriers installation and removal, 2005

Barrier	Installation			Removal		
	Started*	Ended*	DSM2	Started*	Ended*	DSM2
Middle River	5/12/05	5/12/05	5/12/05 1200 hrs	11/8/05	11/8/05	11/7/05 1800 hrs
Old River near DMC	5/31/05	5/31/05	5/31/05 1200 hrs	11/10/05	11/10/05	11/9/05 1000 hrs
Grant Line Canal	7/14/05	7/14/05	7/12/05 1430 hrs	11/15/05	11/15/05	11/14/05 1645 hrs
Old River @ Head (spring)	--	--	--	--	--	--
Old River @ Head (fall)	9/29/05	9/29/05	9/29/05 1500 hrs	11/8/05	11/8/05	11/7/05 1800 hrs

* As reported by Temporary Barriers Program, DWR

The Delta Cross Channel gates were operated in 2005 as shown in Table 9-2.

Table 9-2. Historical Delta Cross Channel Operation for 2005

Time Interval				Status
Date	Time	Date	Time	
1/1/2005	0000	-	6/25/2005 0800	closed
6/25/2005	0800	-	11/16/2005 0800	open
11/16/2005	0800	-	11/20/2005 0800	closed
11/20/2005	0800	-	12/3/2005 0800	open
12/3/2005	0800	-	12/31/2005 2400	closed

Accuracy of DSM2 Simulation of 2005 Delta Hydrodynamics

DSM2-simulated stages and flows have been compared to historical data at various locations in the Delta (Figure 9-6). Most all of the flow and stage data were obtained from DWR's California Data Exchange Center (CDEC) and have not yet been officially screened. For the purpose of this report, obvious errors in the CDEC data were removed. Field-measured flows are actually calculations of flow based on measured velocity and flow depth. New locations in 2005 where stages are reported are Italian Slough (ISH) and the upstream end of Tom Paine Slough (TPP). Flow data was available at eight new sites over the period April 5 through August 8 from a special study of the Mokelumne River system.

Figure 9-7 shows the historical and DSM2-simulated daily maximum and minimum stages at 21 locations in the Delta. DSM2-simulated stages generally followed measured stage. Daily maximum modeled stages well matched field data, but daily minimum stages modeled with DSM2 tended to be ½ to 1 foot lower than what was indicated by field data, with the largest deviations occurring in the summer. DSM2's simulation of the minimum stages upstream of the temporary barriers reproduced the pattern of changes caused by the installation of the barriers in phases: improvement in minimum stages due to the Middle River barrier limited to Middle River; improvement in minimum stages due to the Old River barrier limited to Old River; and improvement in minimum stages due to the later Grant Line Canal barrier installation evident in Grant Line Canal and Old River.

Figure 9-6. Locations where 2005 historical and DSM2-simulated hydrodynamics are compared

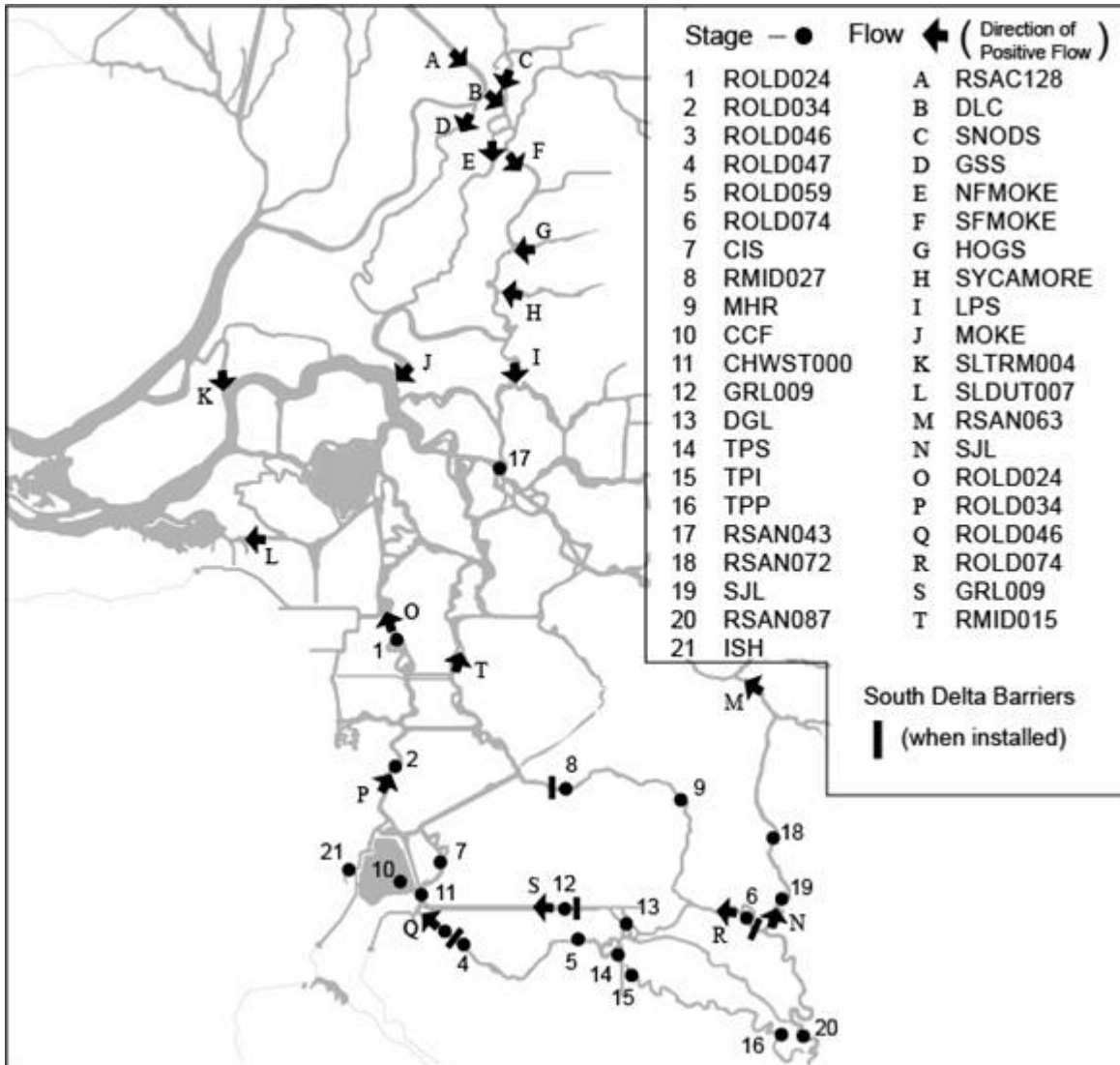


Figure 9-7. Daily maximum and minimum historical and DSM2-simulated stage, 2005

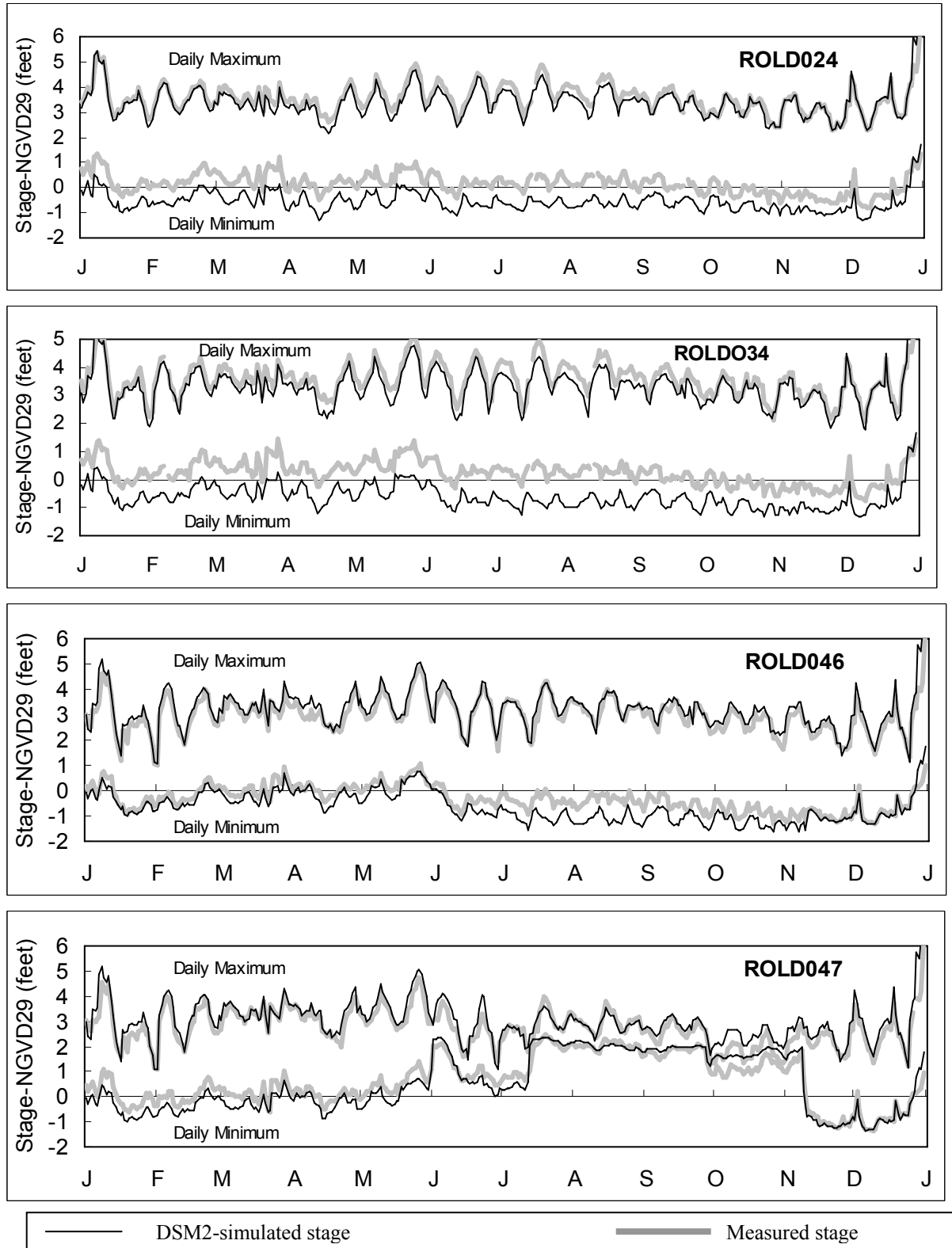


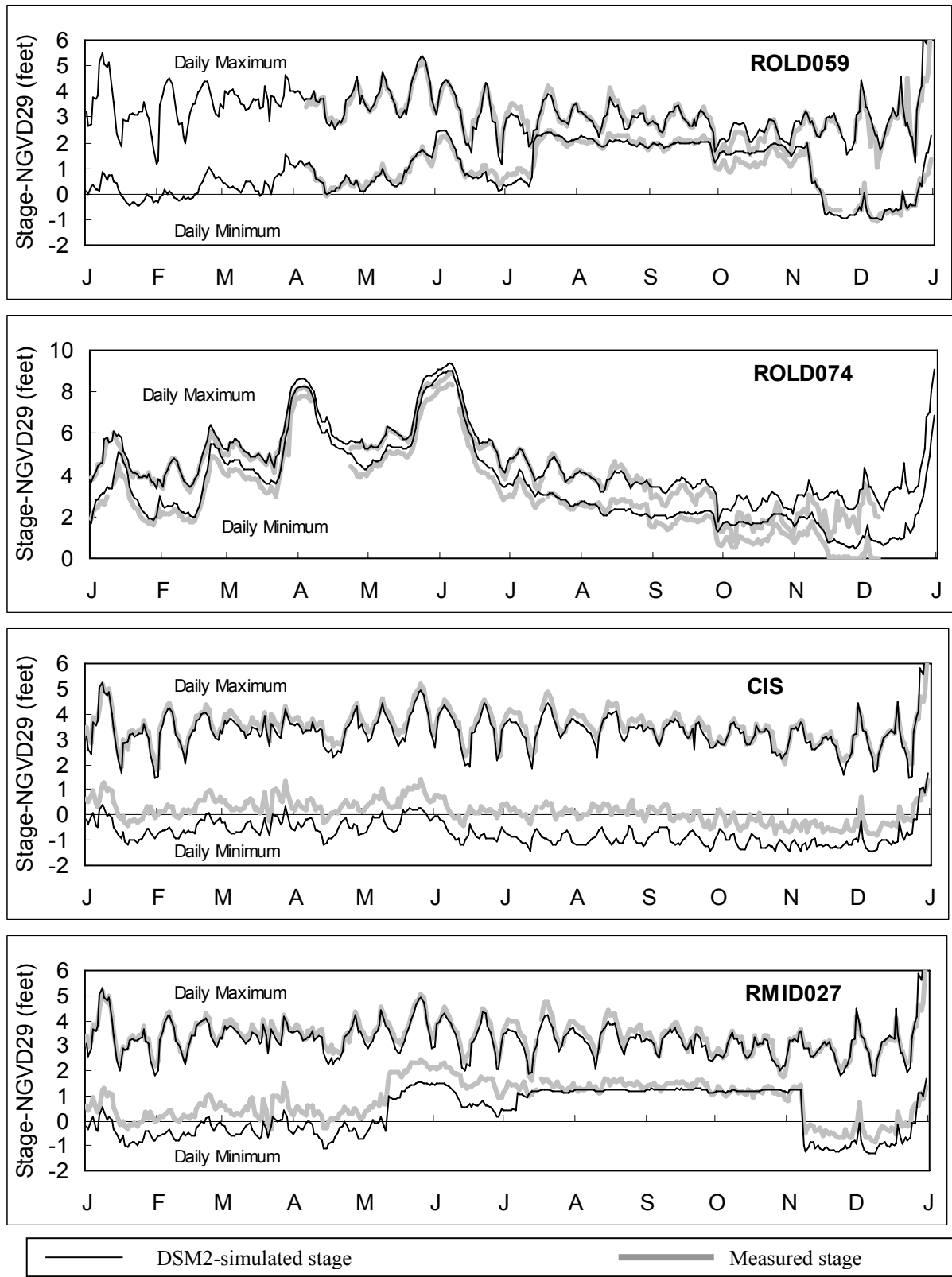
Figure 9-7-cont. Daily maximum and minimum historical and DSM2-simulated stage, 2005

Figure 9-7-cont. Daily maximum and minimum historical and DSM2-simulated stage, 2005

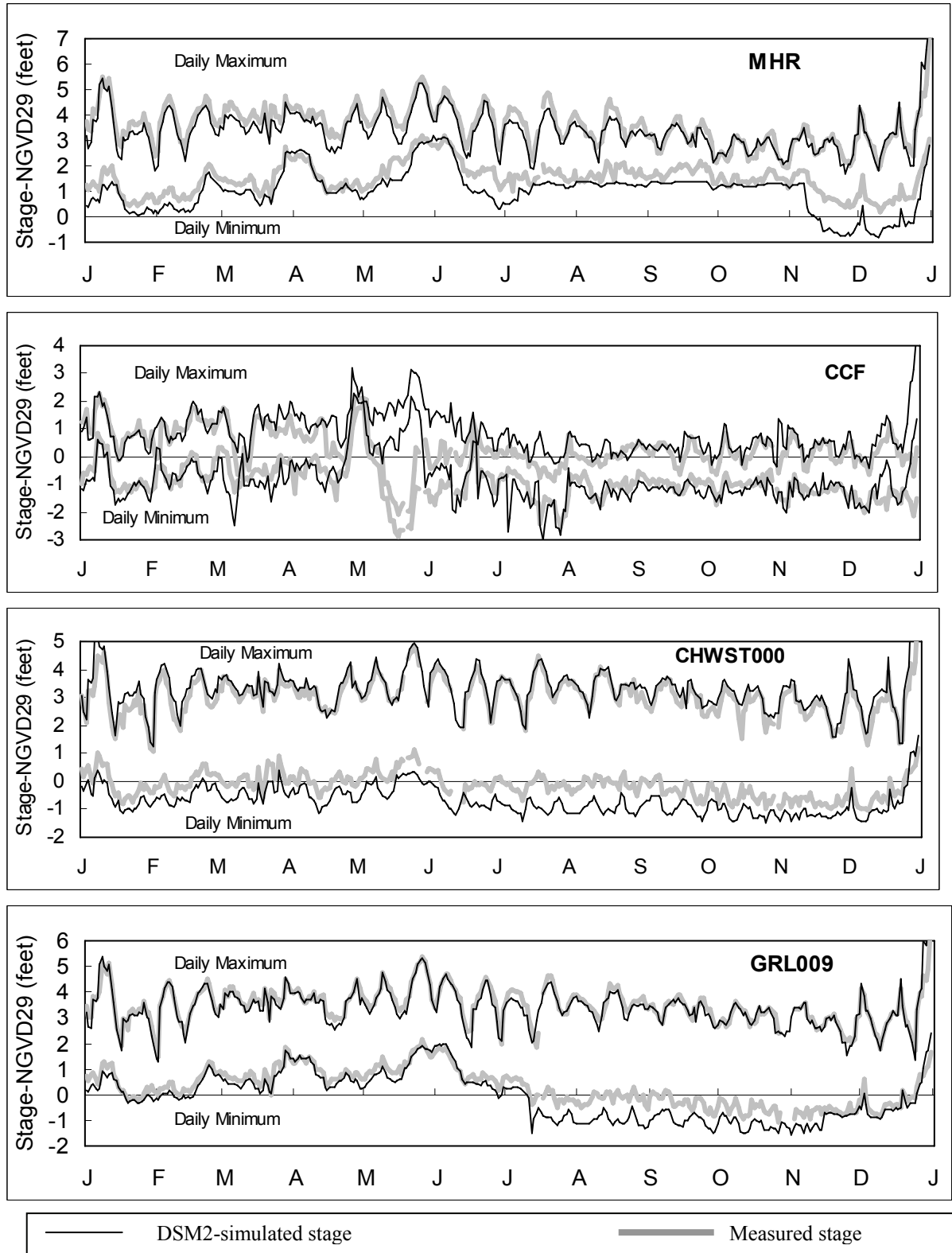


Figure 9-7-cont. Daily maximum and minimum historical and DSM2-simulated stage, 2005

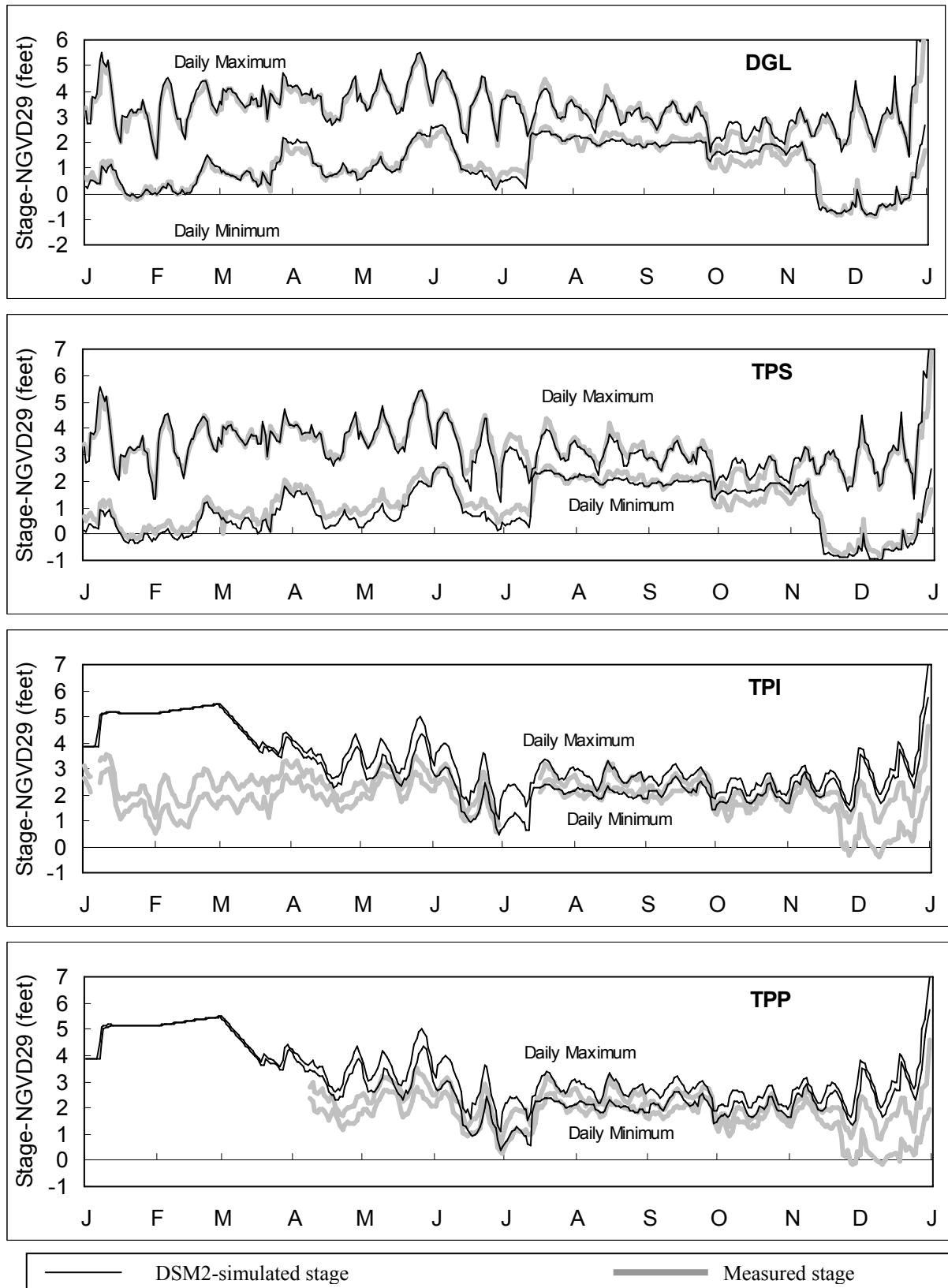


Figure 9-7-cont. Daily maximum and minimum historical and DSM2-simulated stage, 2005

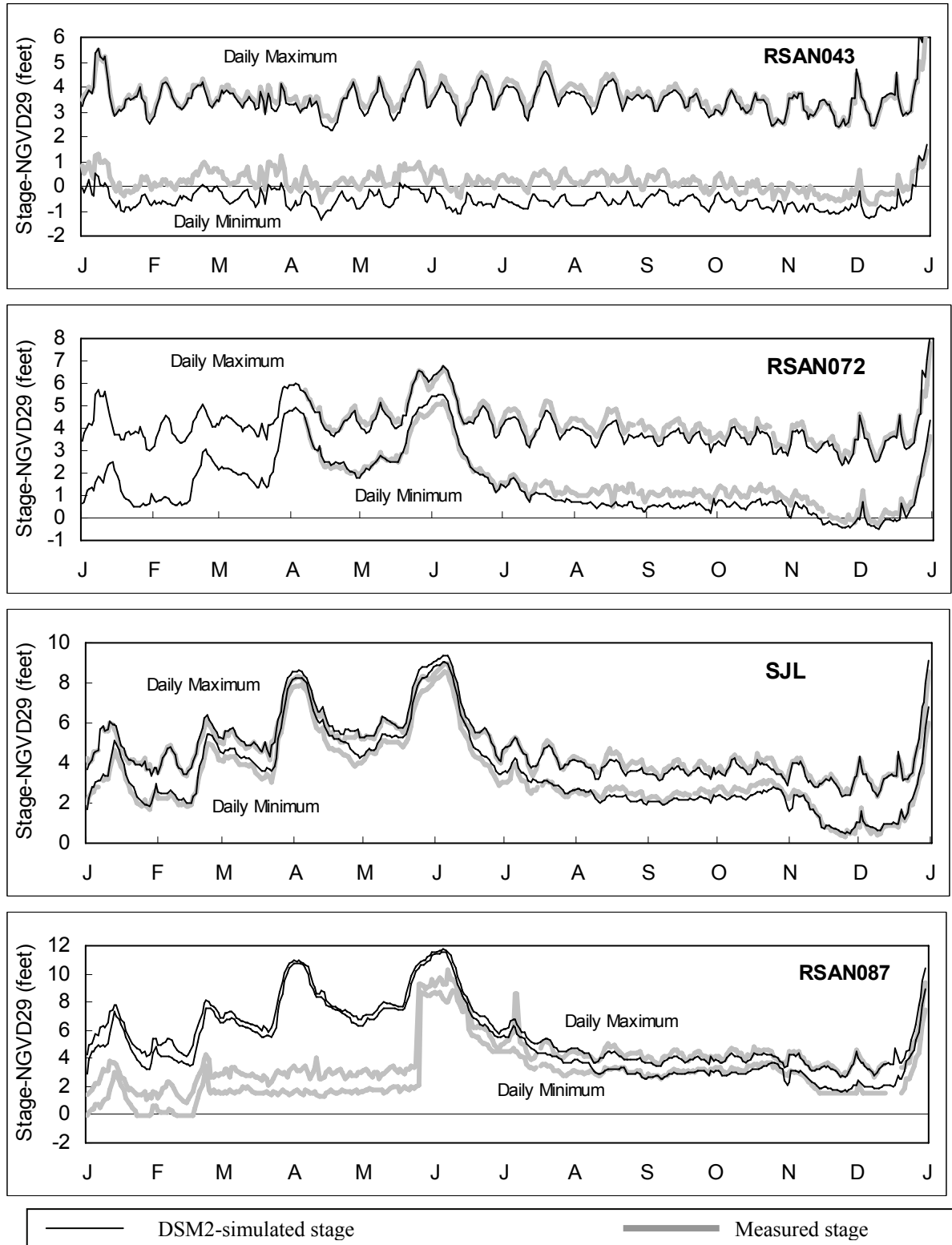
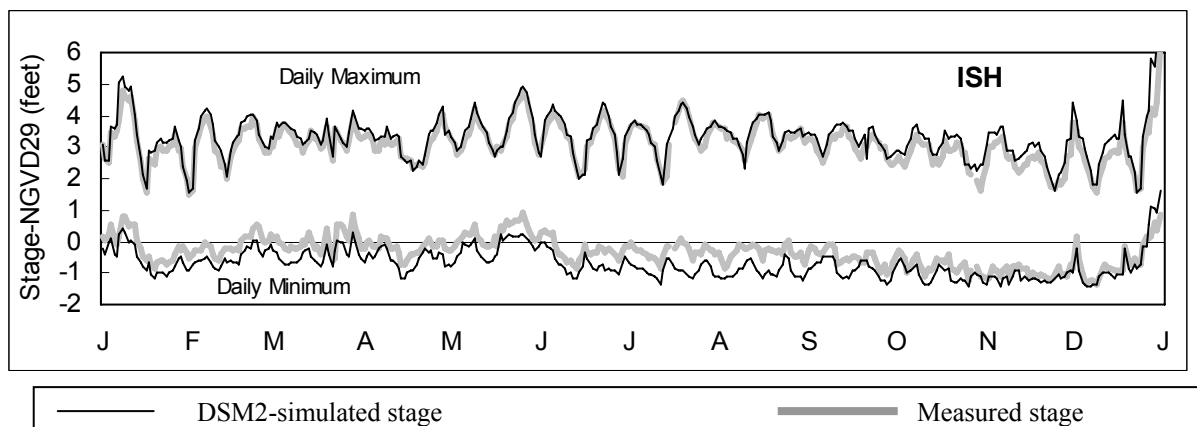
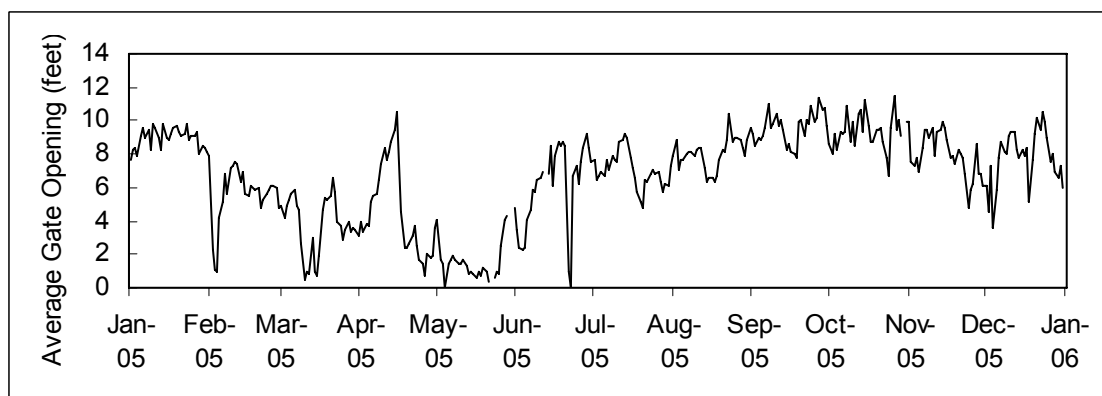


Figure 9-7-cont. Daily maximum and minimum historical and DSM2-simulated stage, 2005

As in previous simulations of historical conditions, the DSM2 simulation of stages at times significantly varied from field data in Clifton Court Forebay and Tom Paine Slough. Water levels in Clifton Court Forebay sharply decreased in May of 2005 corresponding to a time of decreased pumping at Banks Pumping Plant and decreased average opening of the five Clifton Court Forebay intake gates (see Figure 9-8). Currently, DSM2 cannot simulate partial openings of these intake gates. When hourly records of gate positions show any opening, DSM2 assumes a complete opening. Due to this limitation in DSM2, the simulation of historical 2005 Delta conditions allowed too much water to flow into Clifton Court Forebay in May and the actual decrease in water stage that occurred was not captured. This has been noticed in simulations of historical water levels in Clifton Court Forebay in previous years.

Figure 9-8. Daily Average Clifton Court Forebay Intake Gate Opening, 2005

DSM2-simulated water level inside Tom Paine Slough failed to follow actual water levels during in January, February, March, and December of 2005 (see results at stations TPI and TPP). DSM2's simulation of water levels in Tom Paine Slough is dependent upon the flow through the intake structure/siphons and the agricultural diversions from the slough. A previous study of DSM2's simulation of Tom Paine Slough's water levels indicated that pumping from the slough may be substantially higher in the summer months than is assumed in the current historical simulations and that there may be some drainage of water back through the intake structure. The reasons for the observed water levels in the winter and late fall of 2005 need further investigation.

Historical and DSM2-simulated daily maximum, minimum, and average flows at 20 locations in the Delta were compared (Figure 9-9). By common sign convention, positive flows refer to downstream flow while negative flow corresponds to upstream flow (see Figure 9-6). Minimum flows then generally correspond to peak flow in the upstream direction. When taken together, peak flow in upstream and downstream directions at any location in the Delta indicate the tidal flux at that location. The daily average, maximum, and minimum flows simulated by DSM2 generally matched measured data. Notable exceptions were at RSAC128 (Sacramento River upstream of the Delta Cross Channel), GSS (Georgiana Slough), ROLD024 (Old River at Bacon Island), and GRL009 (Grant Line Canal).

At RSAC128, the observed flow data sharply increased in mid May and then sharply decreases in mid June, a pattern not captured by the DSM2 simulation. The amount of increase in flow in mid May observed here exceeds the increase reported further upstream at Freeport. Considering the subsequent sudden decrease in observed flow in mid June back to levels simulated by DSM2, the observed flow data from mid May to mid June appear suspect. At GSS, simulated flow from mid January through mid February ranged from approximately 2,000 to 4,000 cfs too high and approximately 4,000 cfs too low during the pulse in Sacramento inflow in May.

At ROLD024, DSM2 consistently overestimated the upstream tidal flow by approximately 5,000 cfs which resulted in simulated average flows being approximately 2,000 cfs too low.

At GRL009, DSM2-simulated flows, similar to the historical 2004 simulation, were from about 2 to 3,000 cfs lower than observed values. When the observed flow at the head of Old River is compared to the observed flow in Grant Line Canal (below), it is likely that one or both of the observed flows was off since the source of flow in Grant Line Canal is primarily the flow from the San Joaquin River down Old River and so is normally expected to be less than the flow down Old River (see Figure 9-13).

Figure 9-9. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

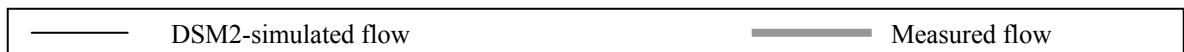
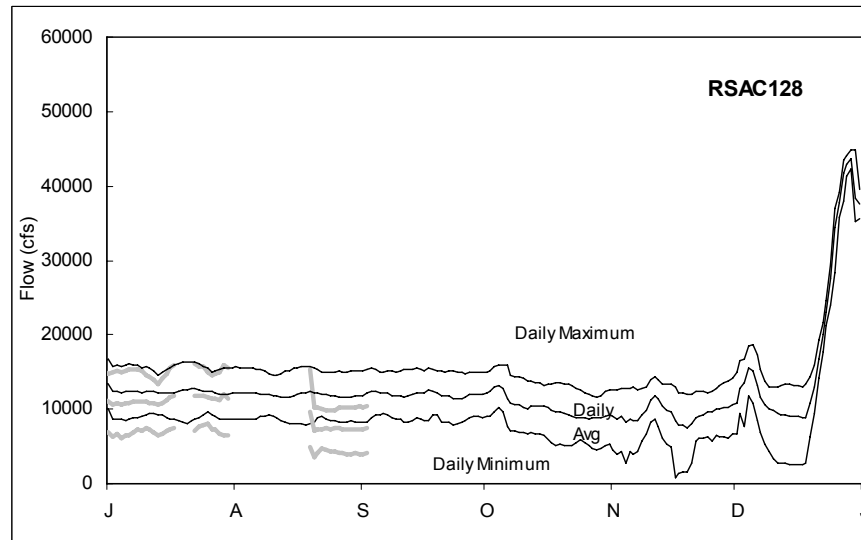
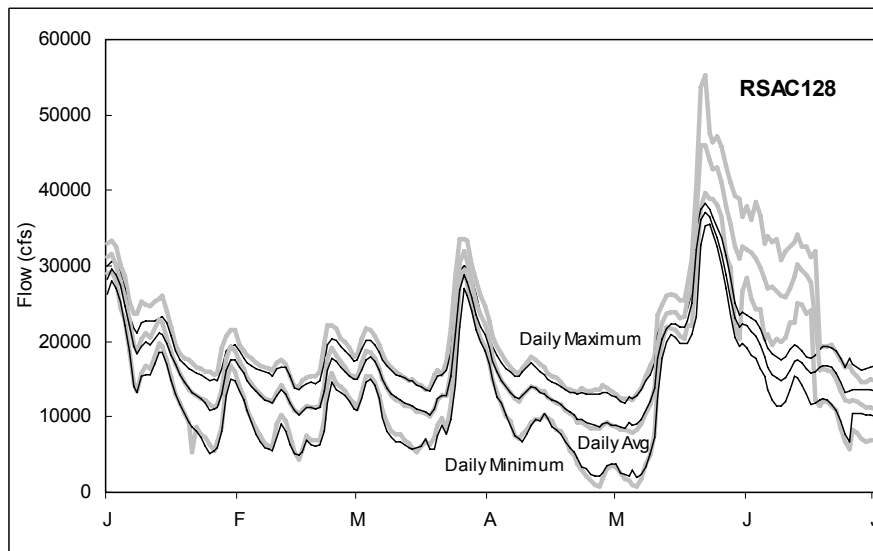
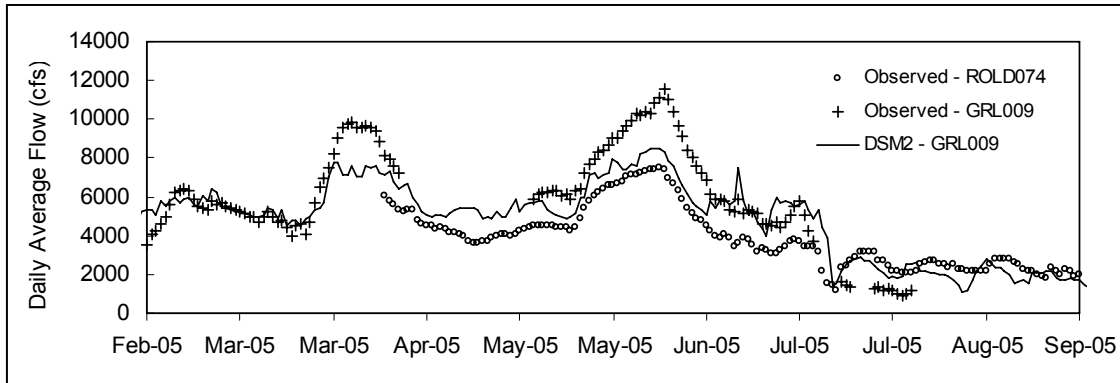


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

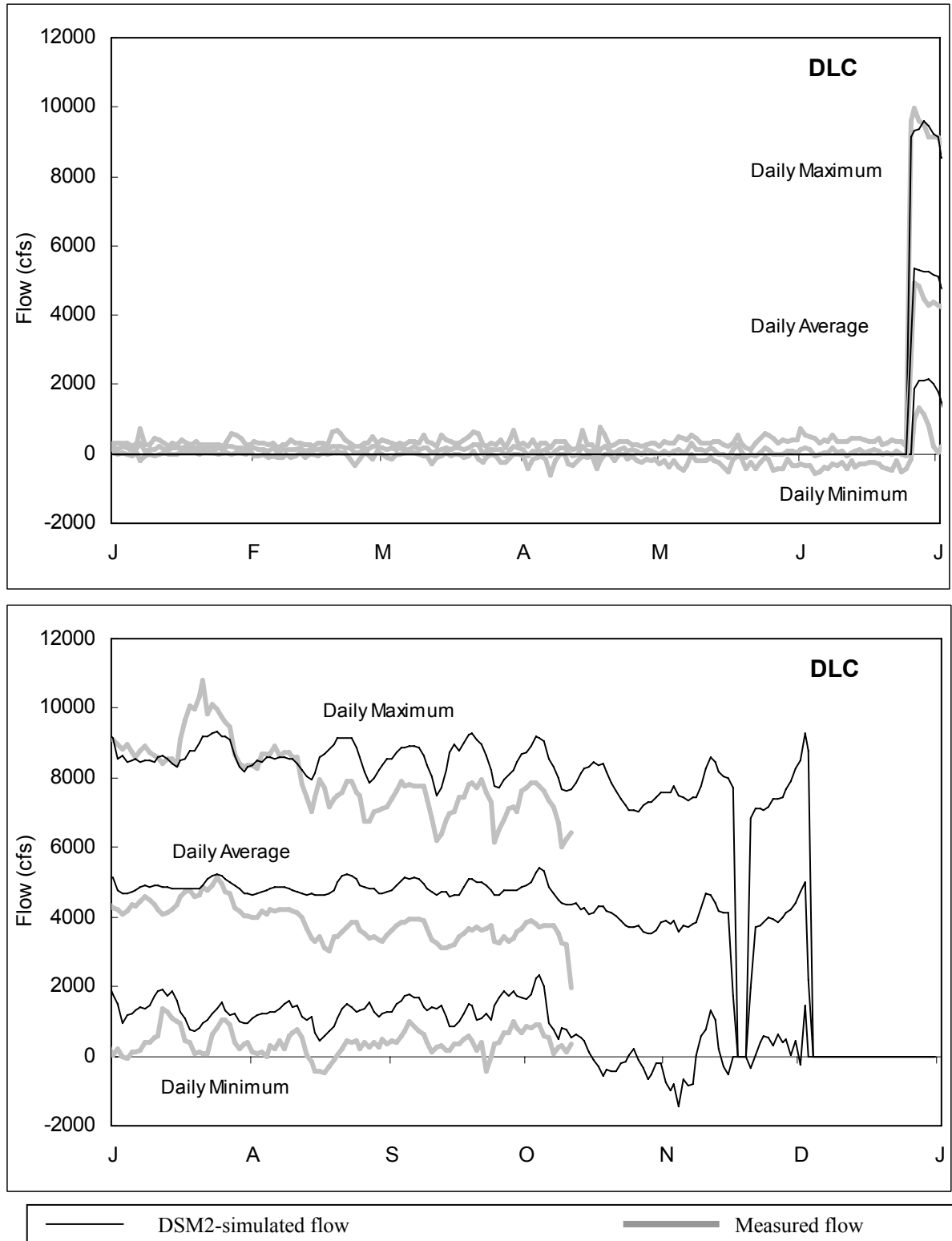


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

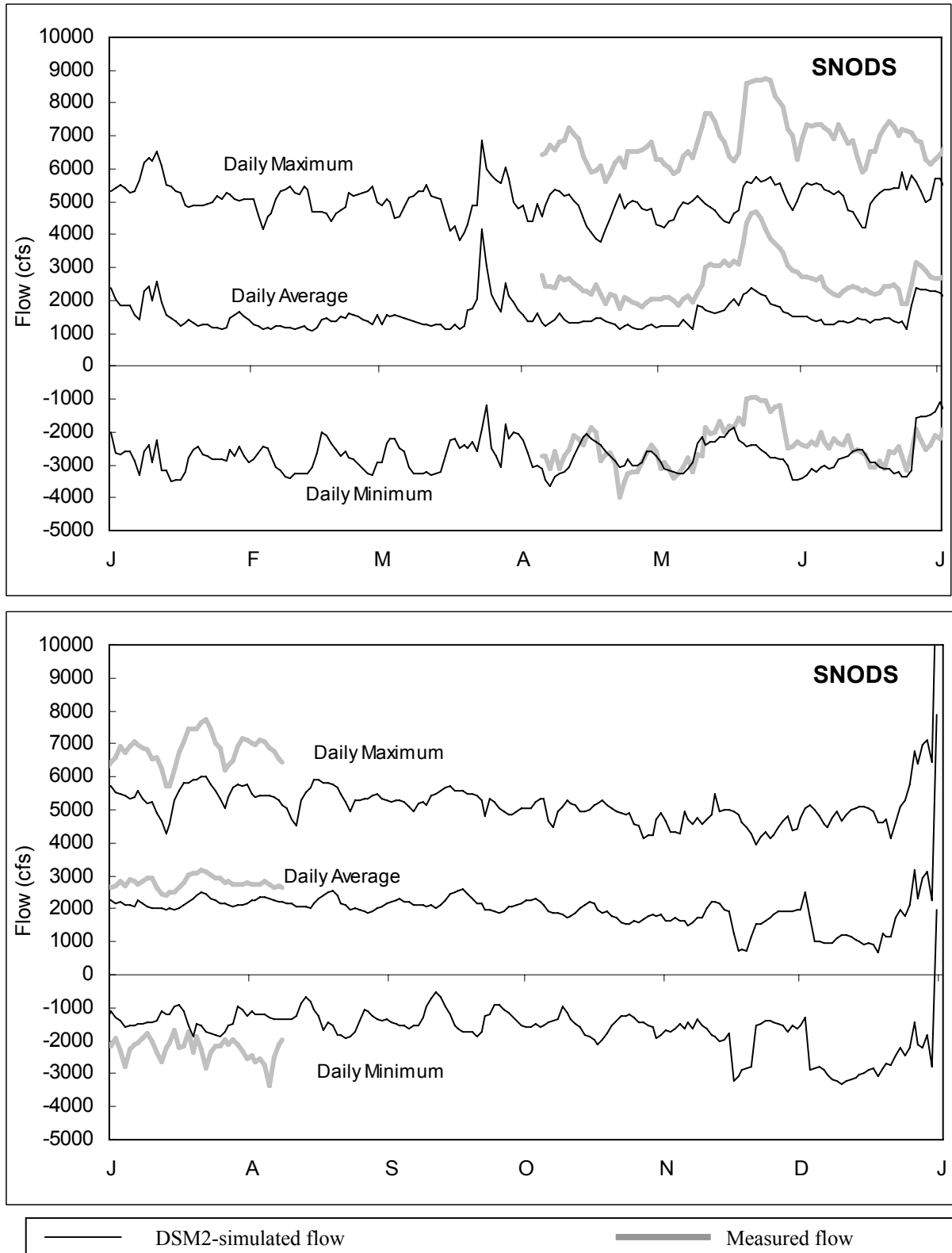


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

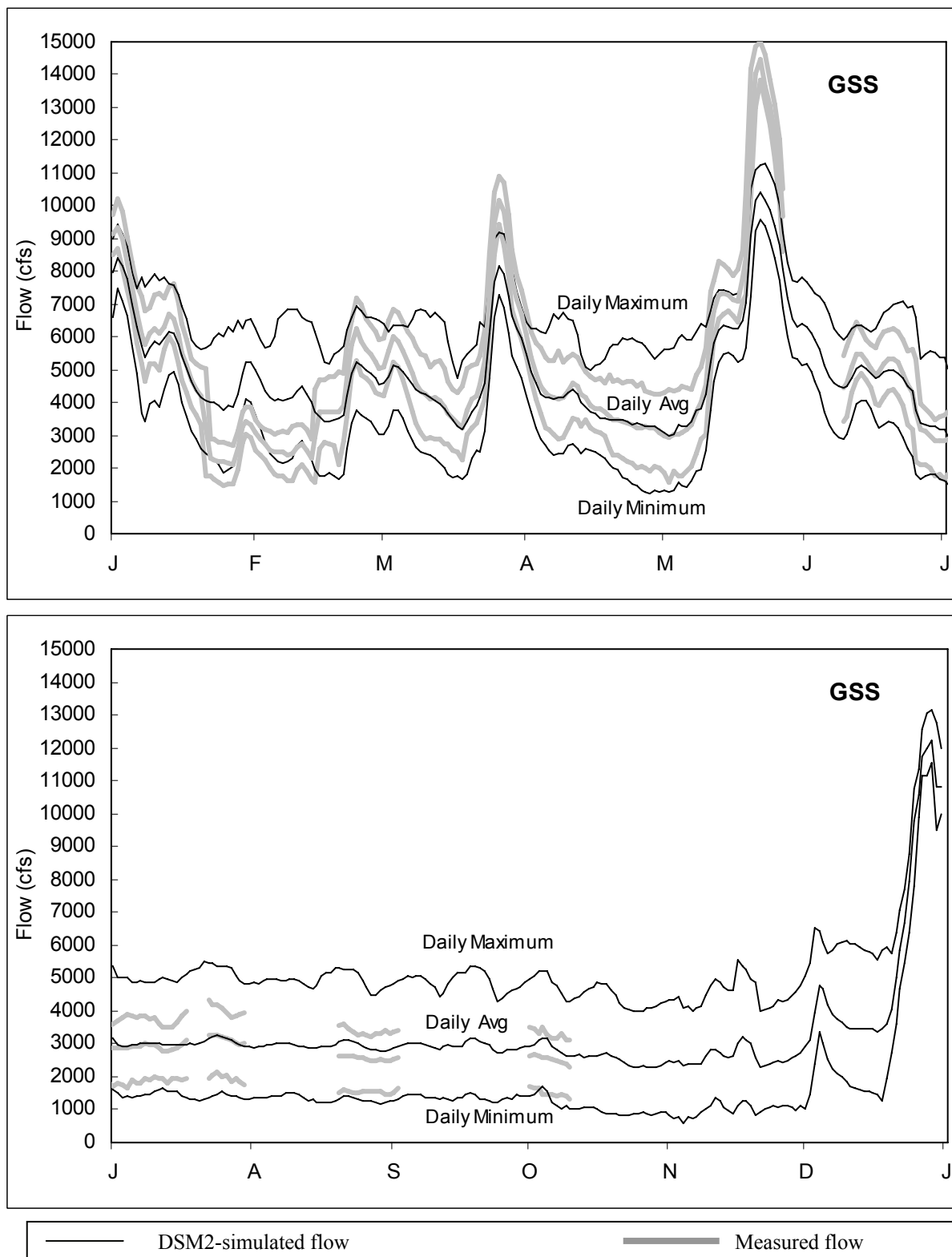


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

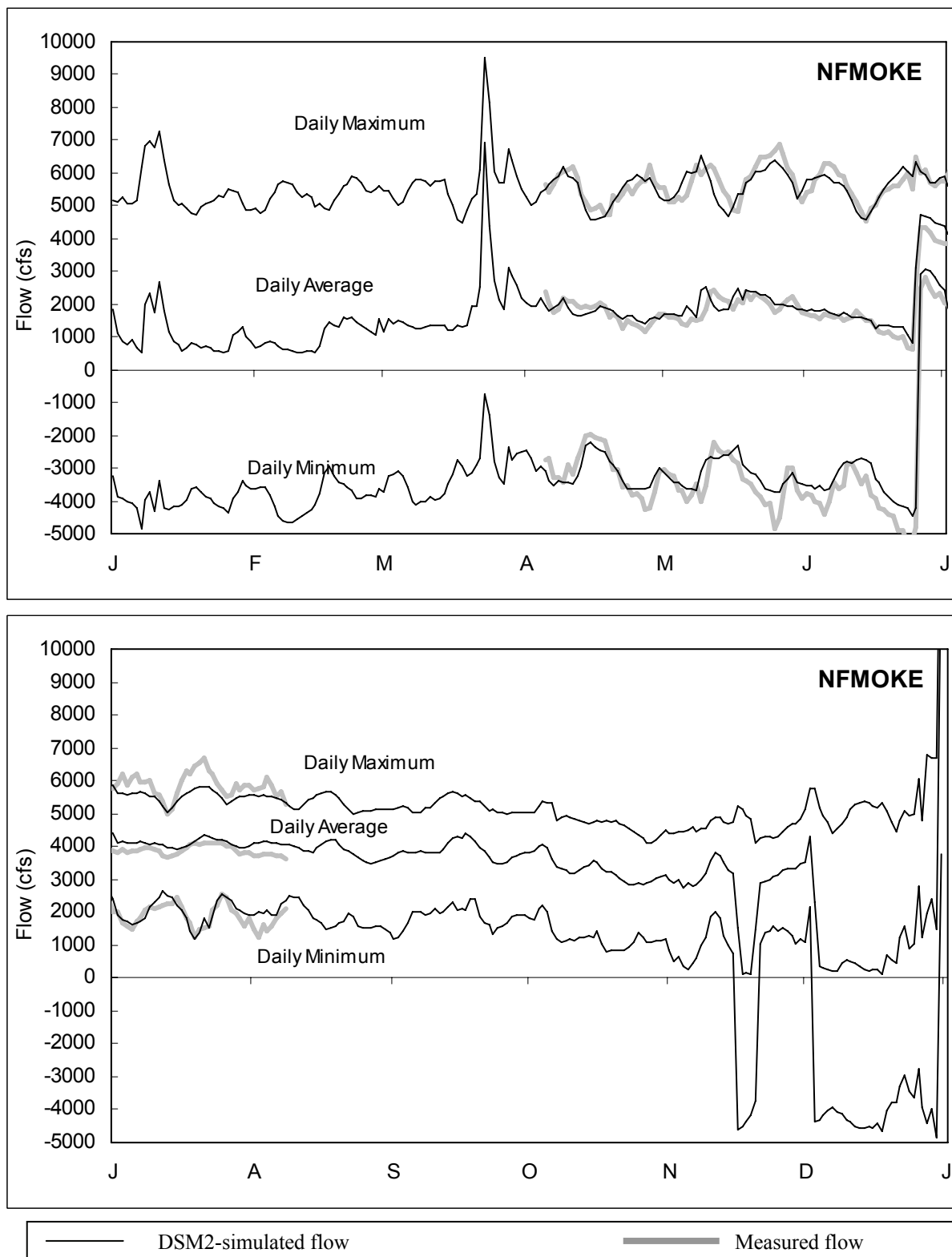


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

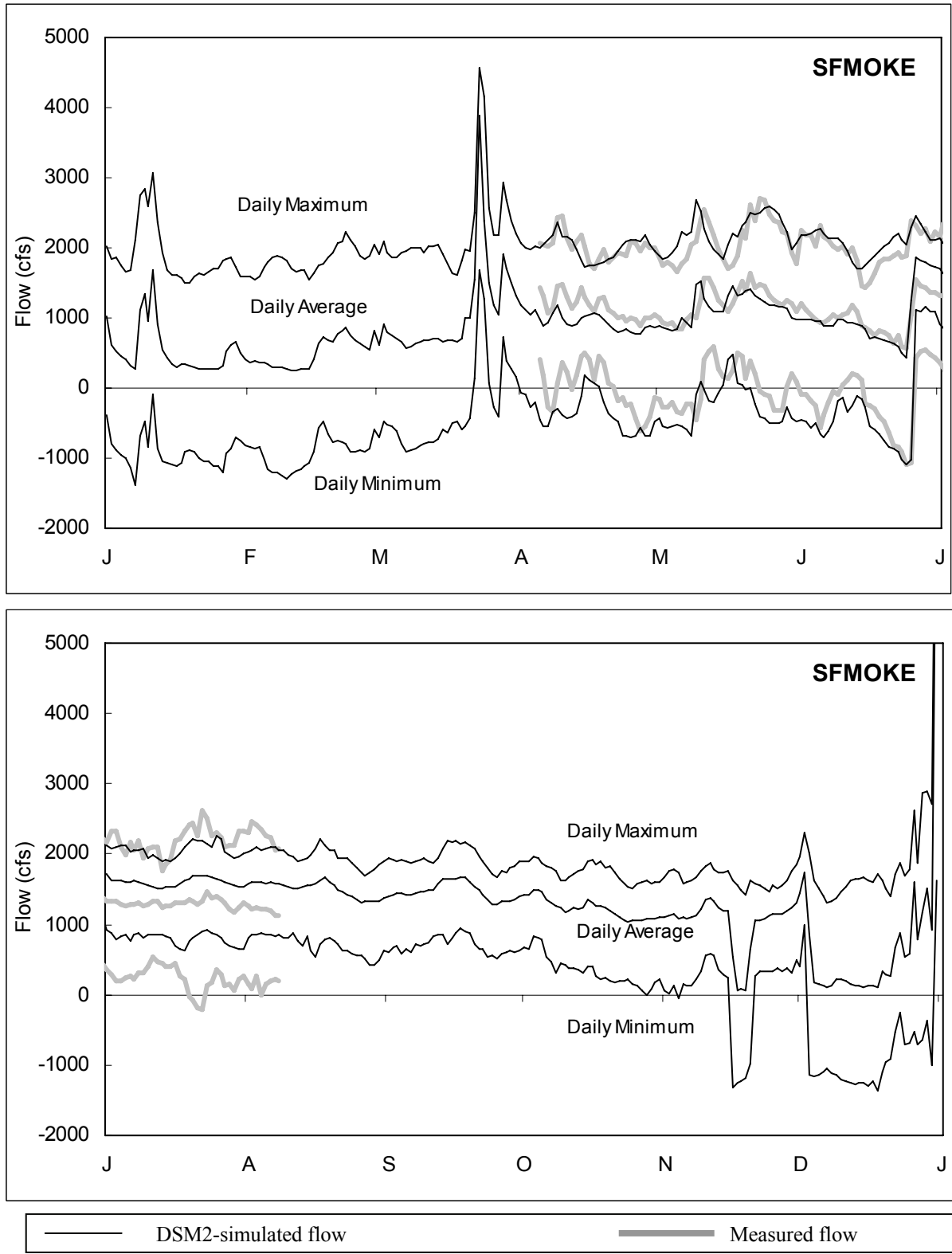


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

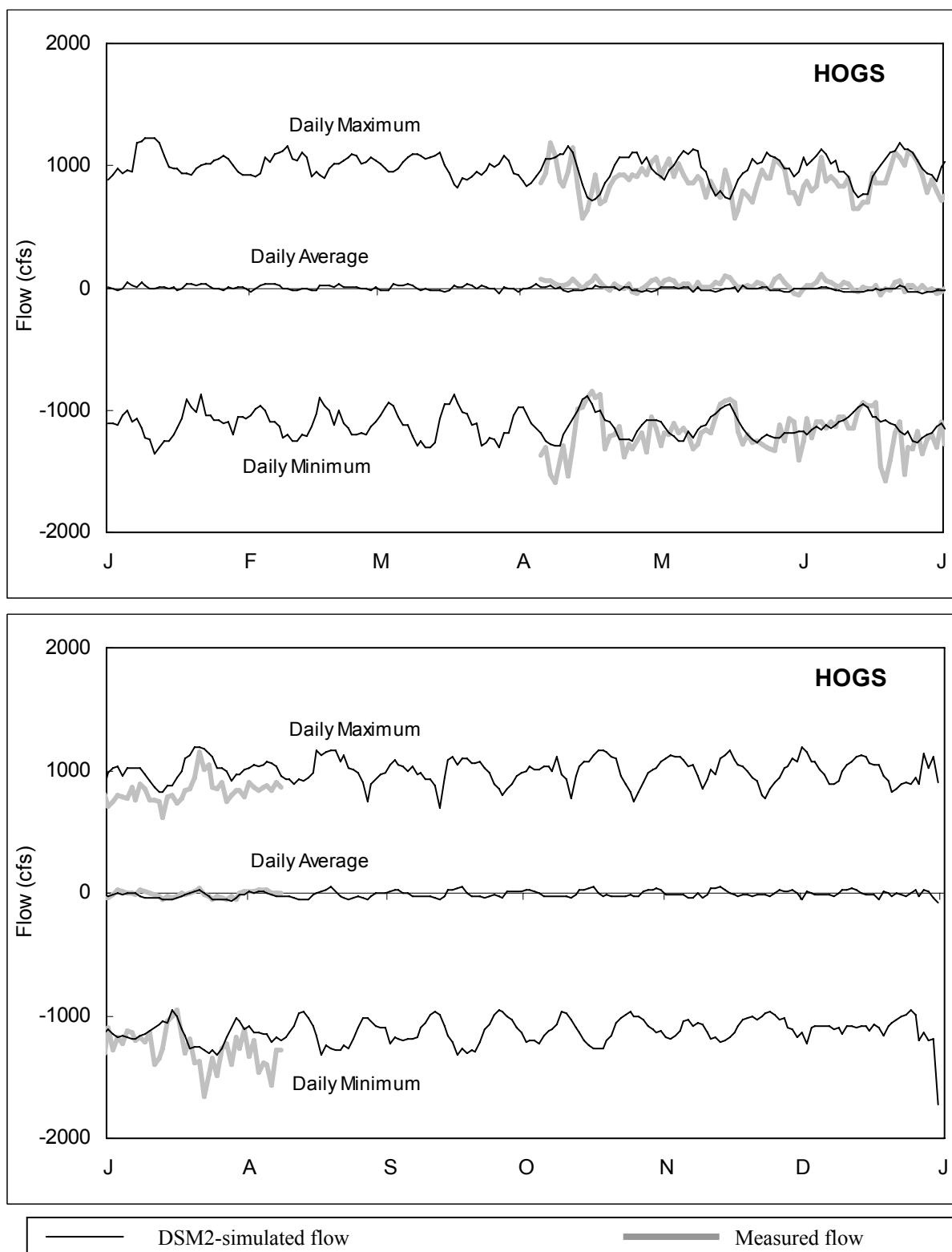


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

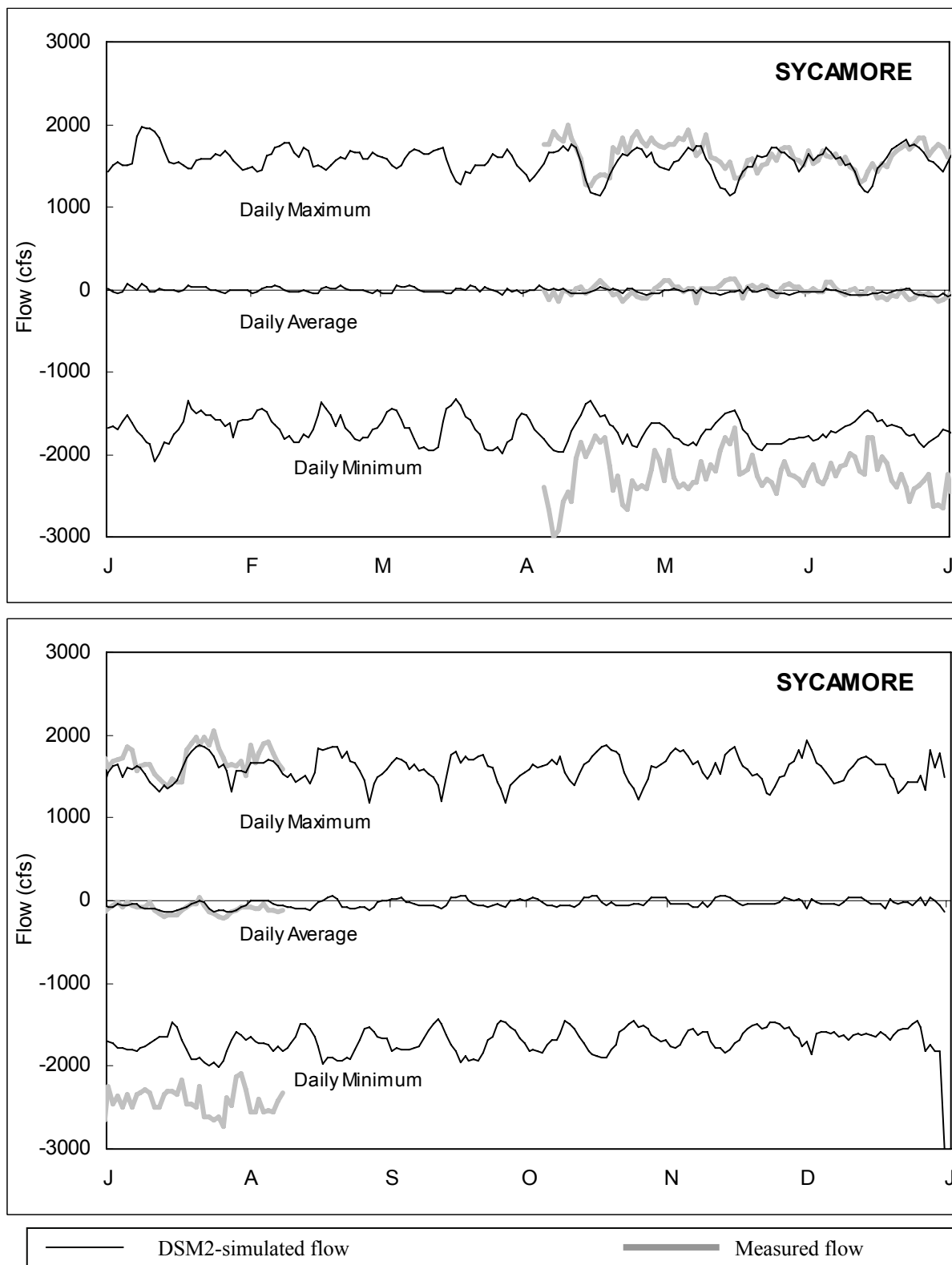


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

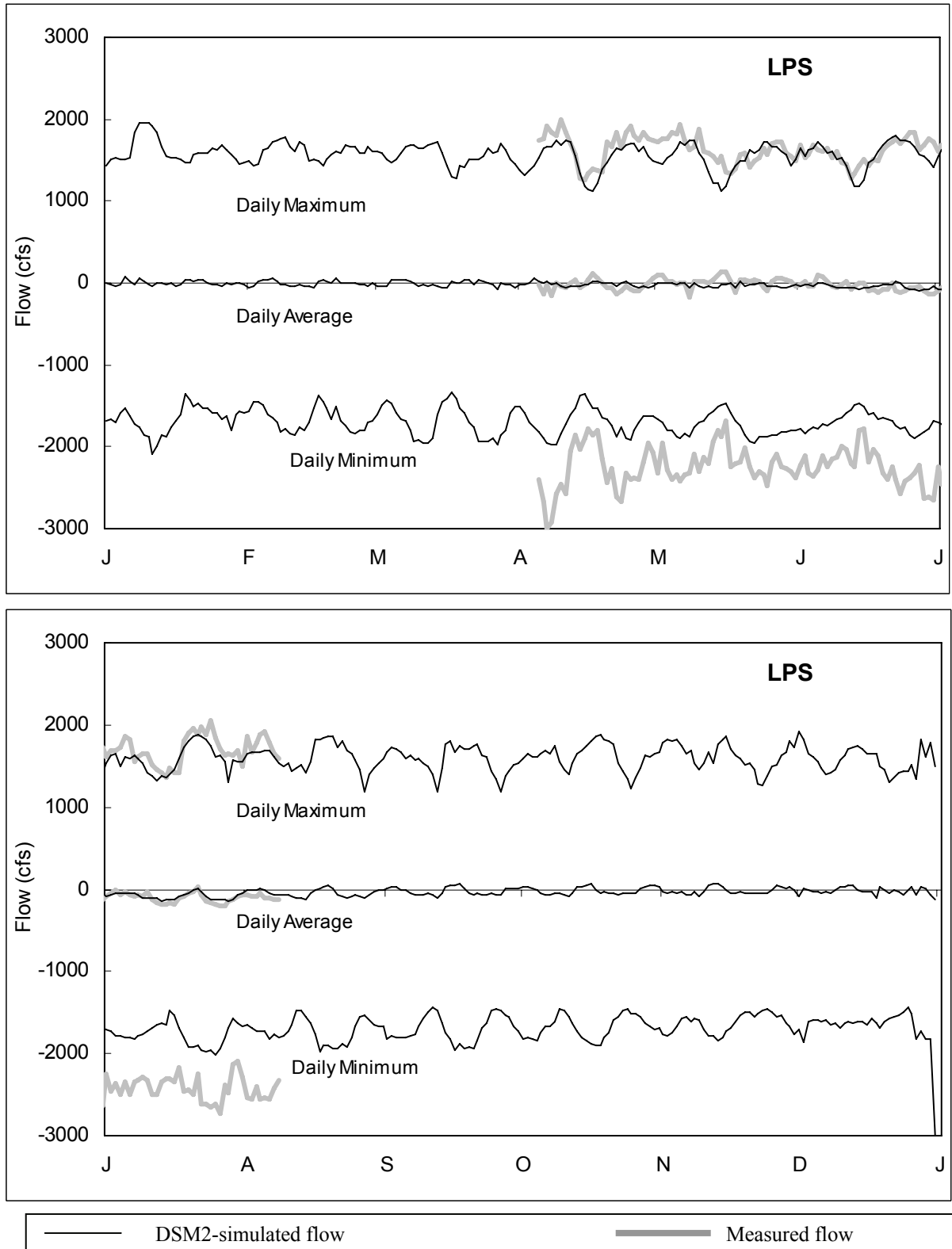


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

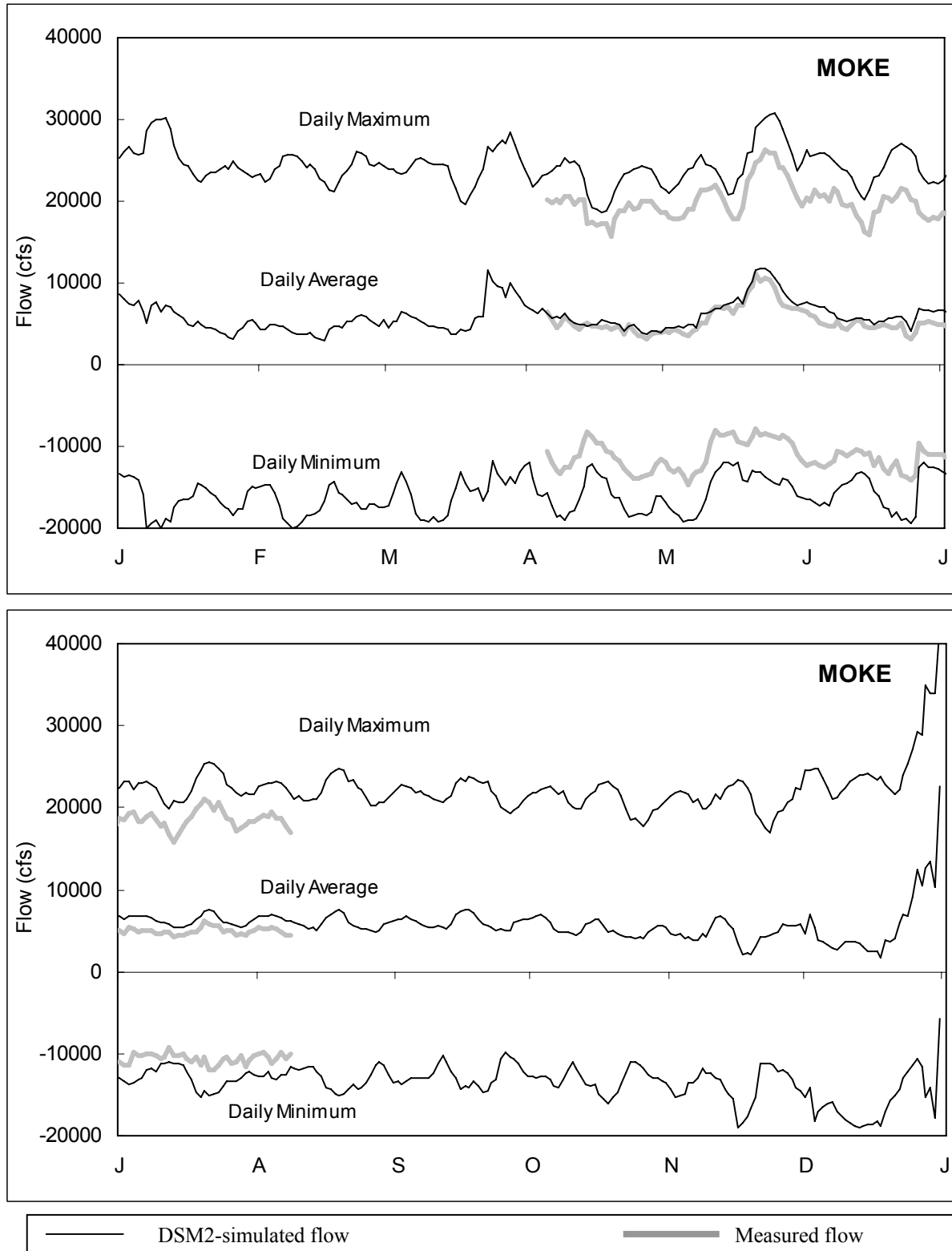


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

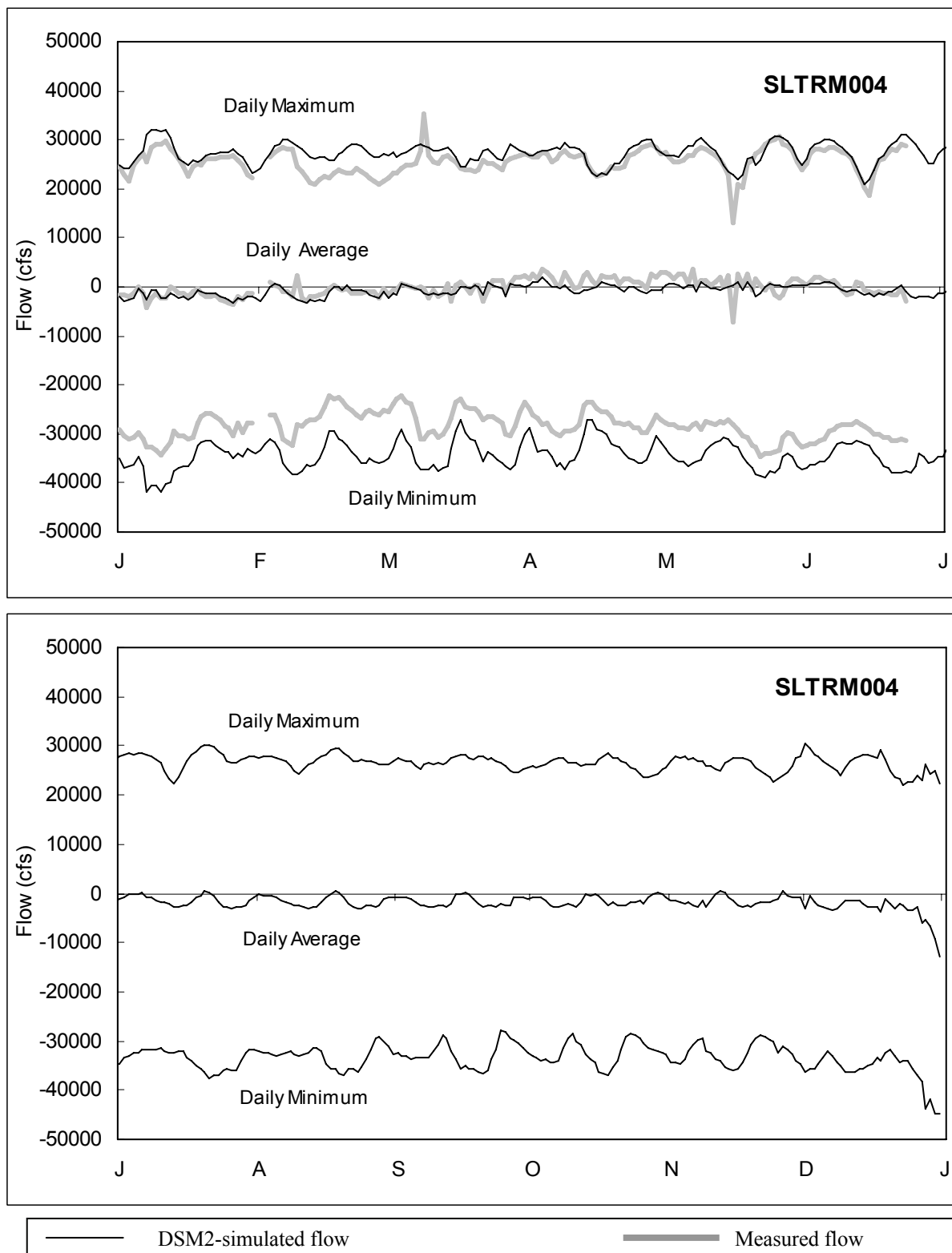


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

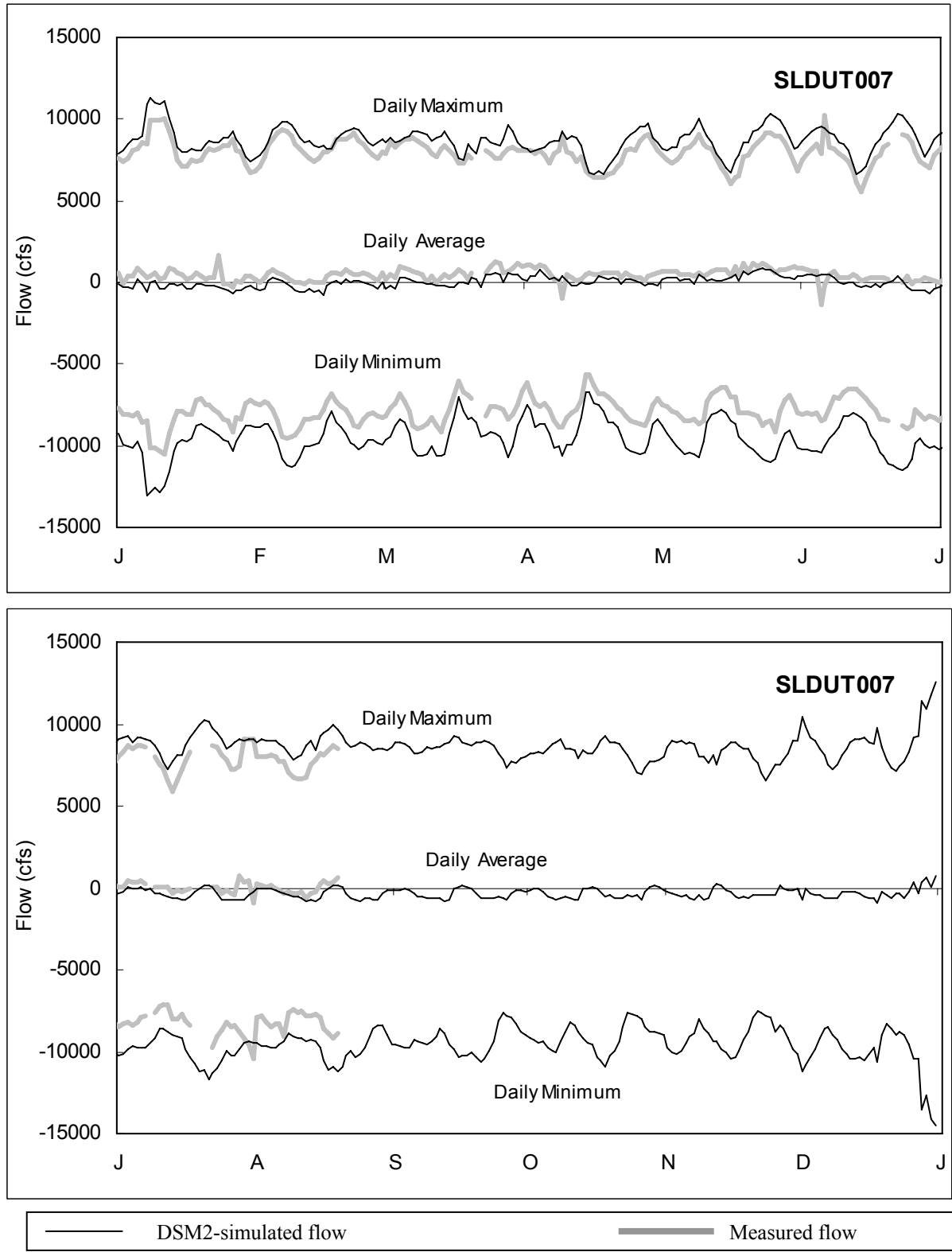


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

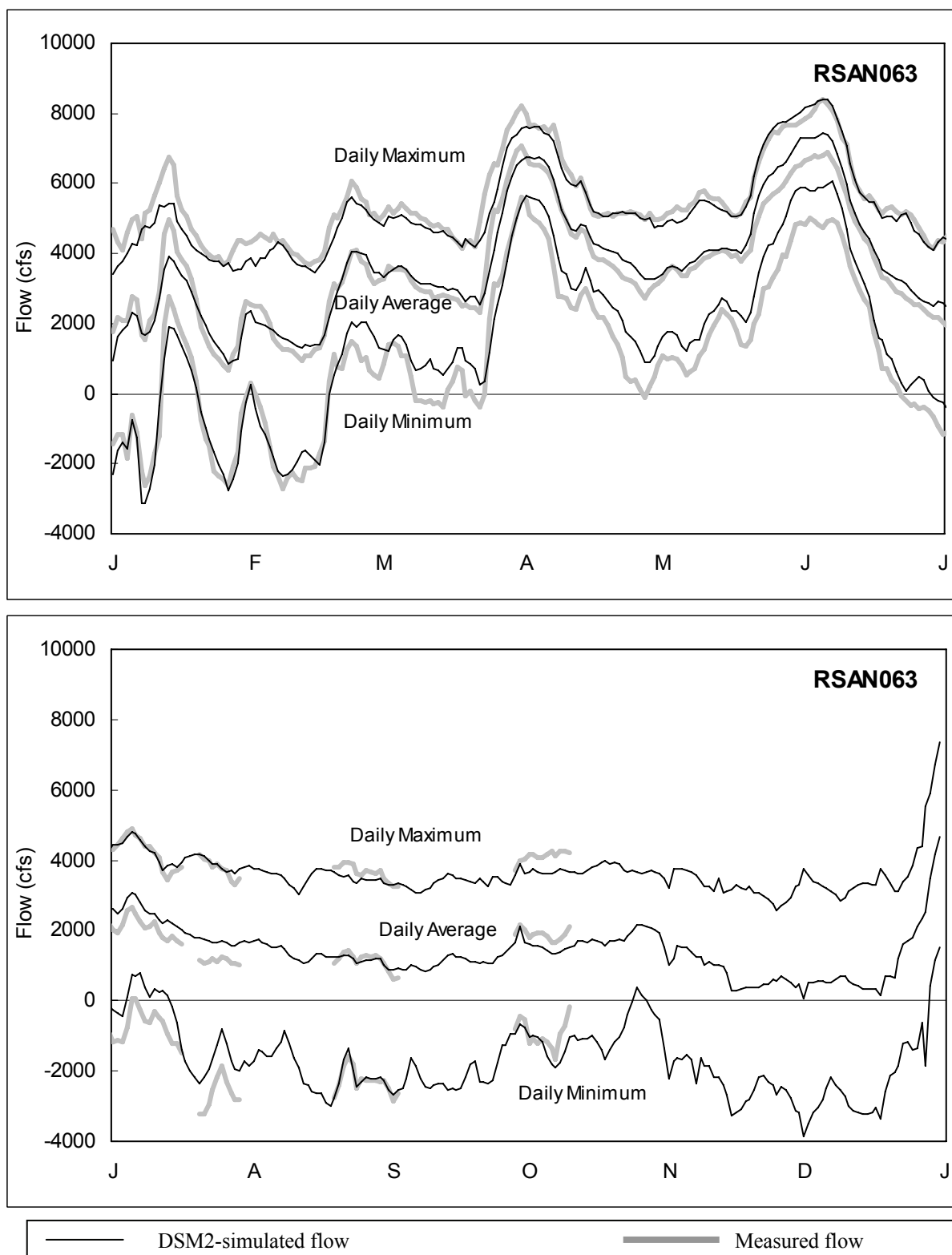


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

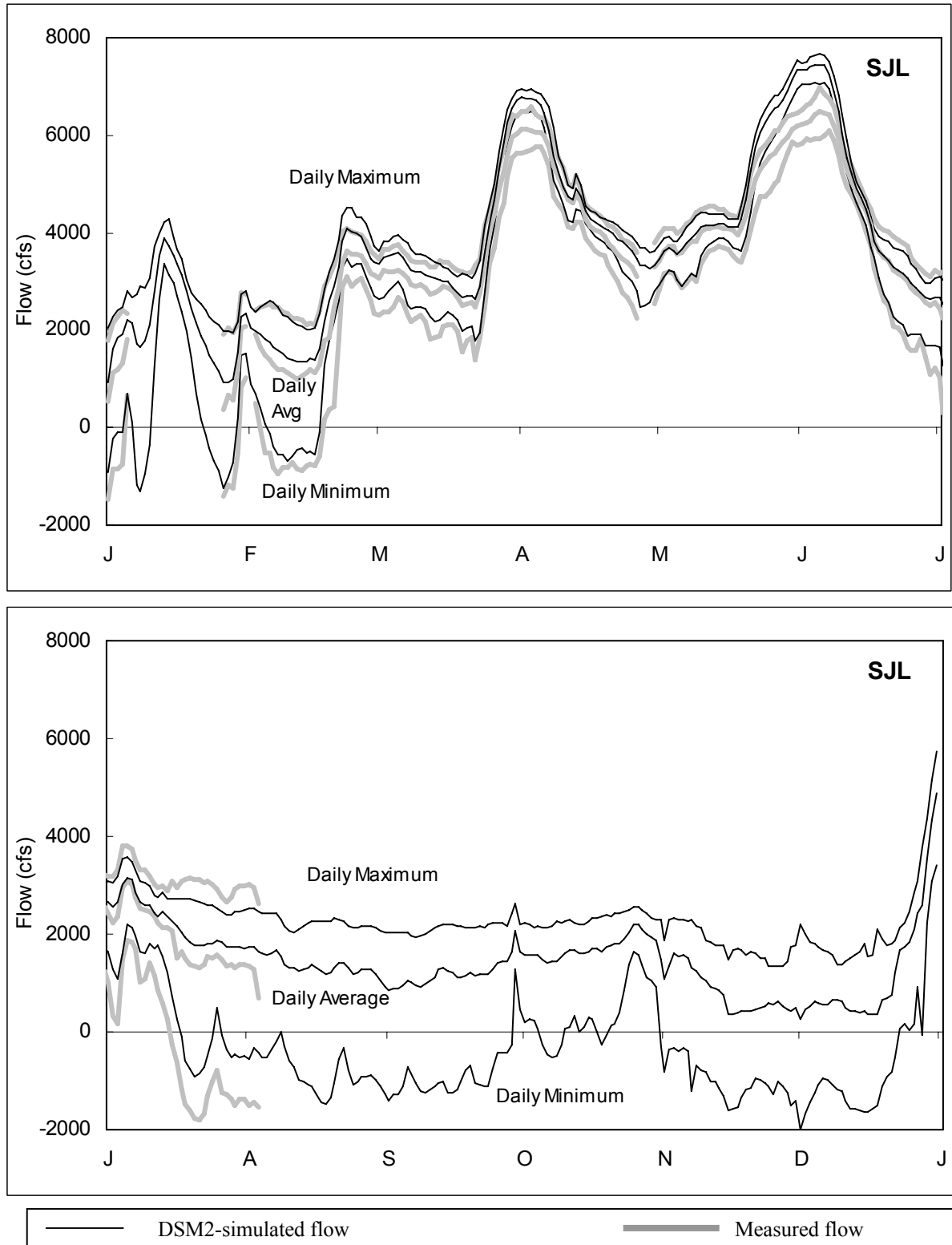


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

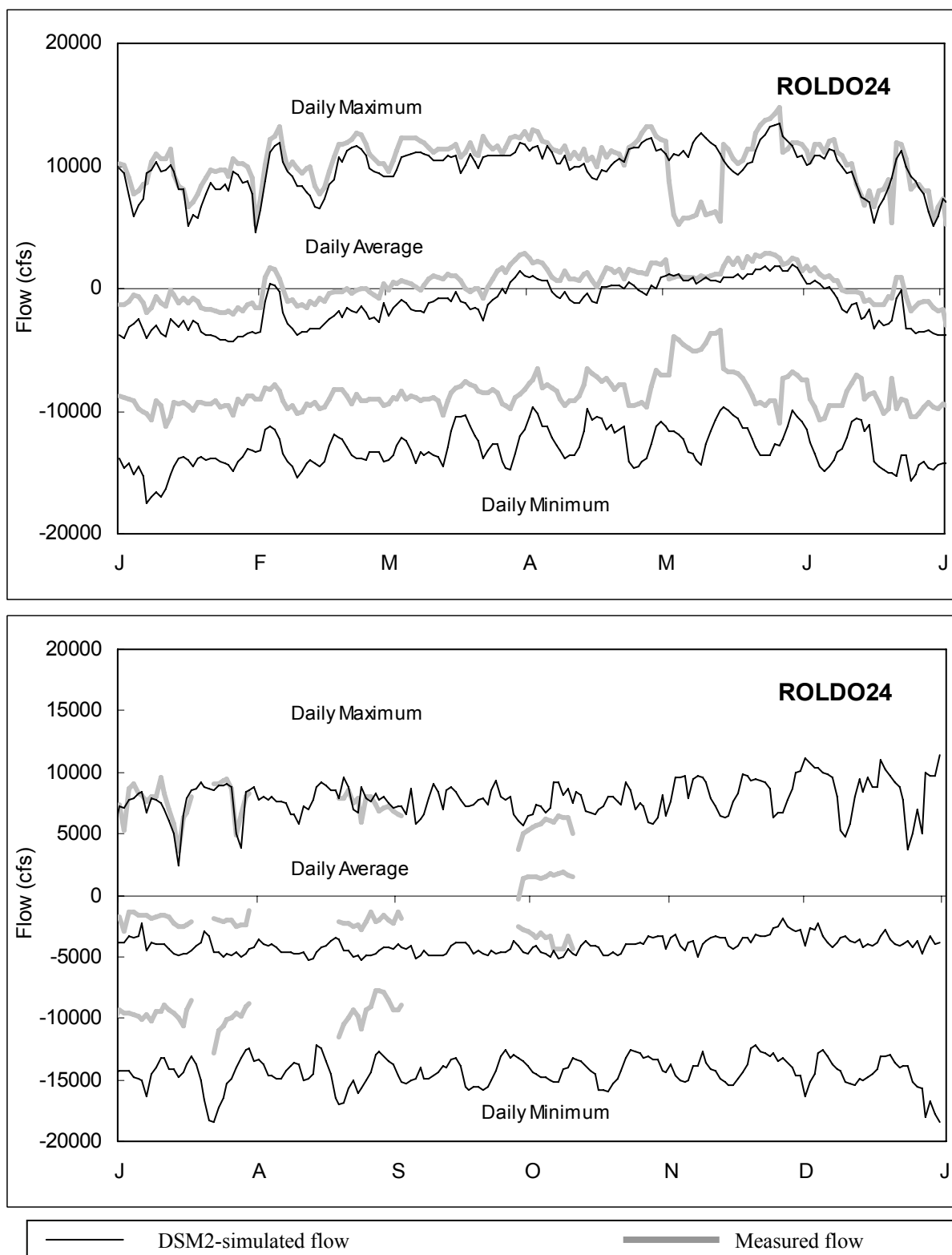


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

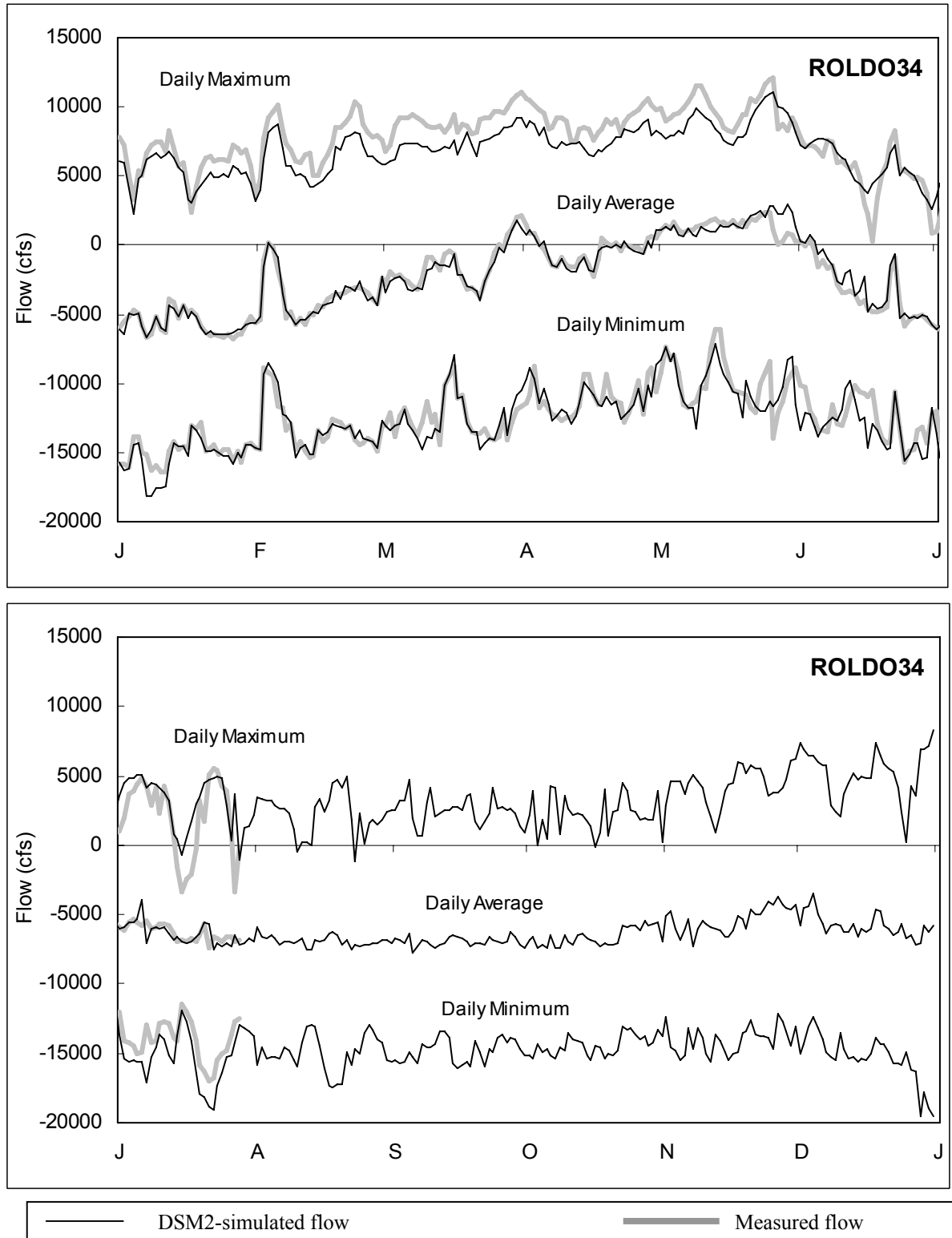


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

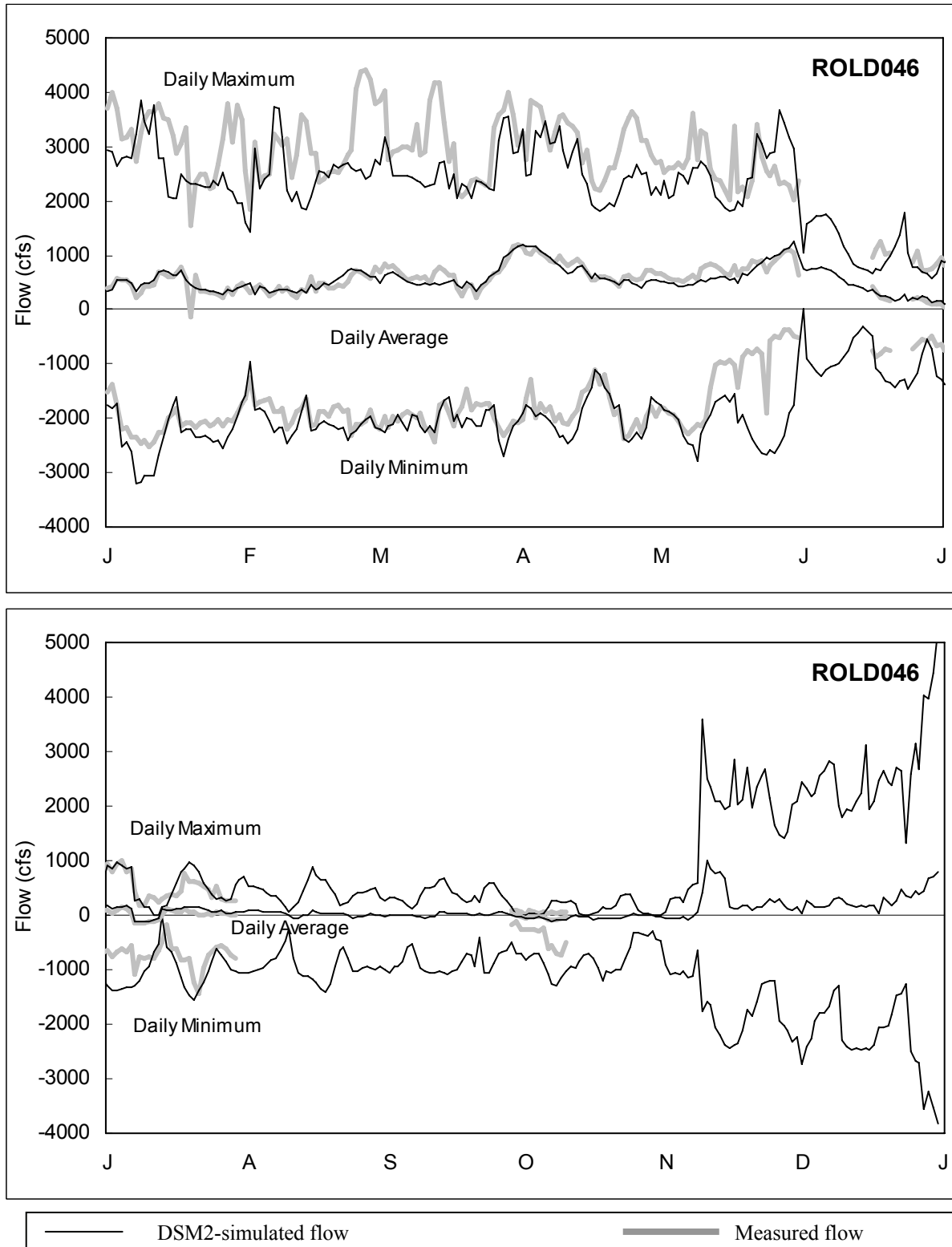


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

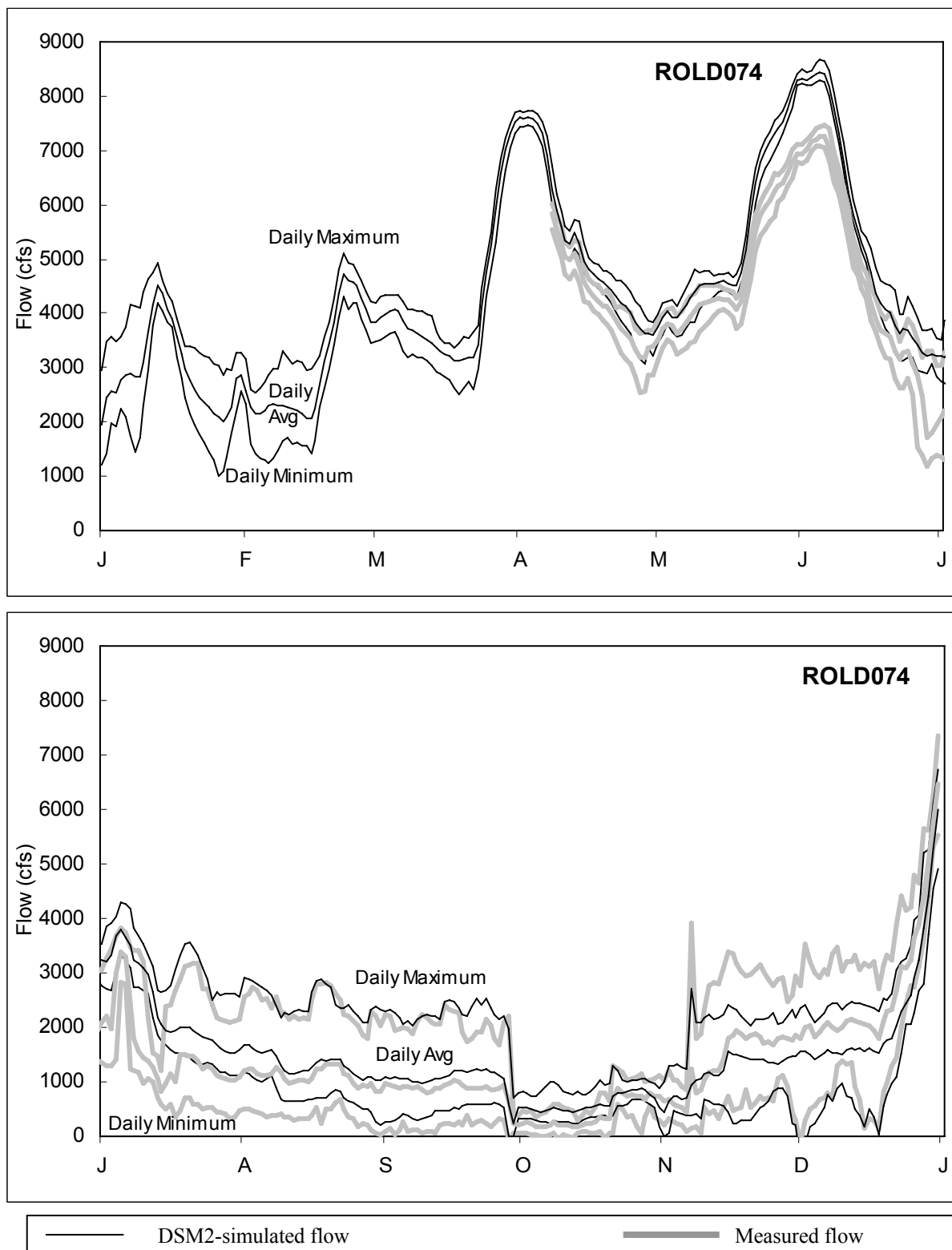


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005

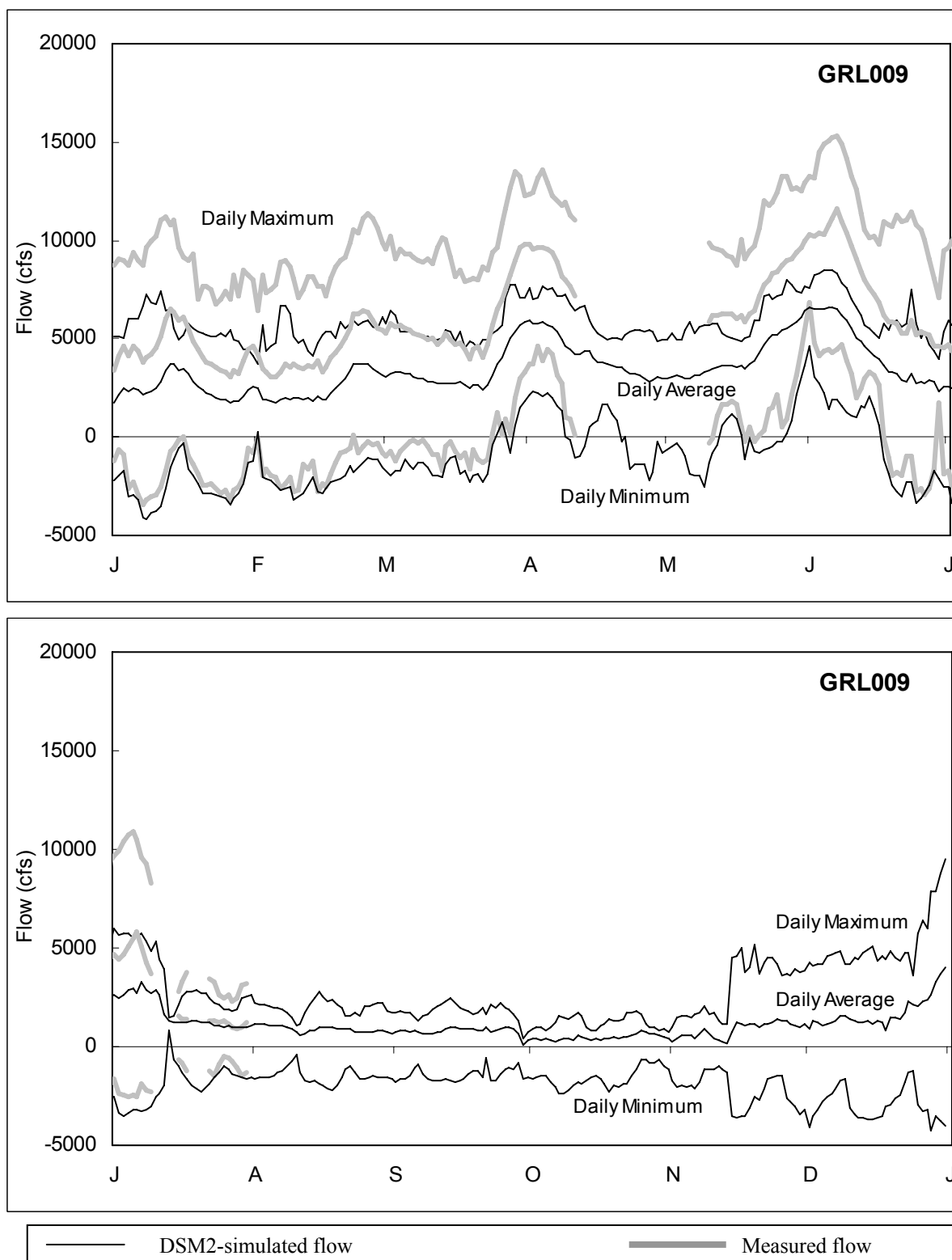
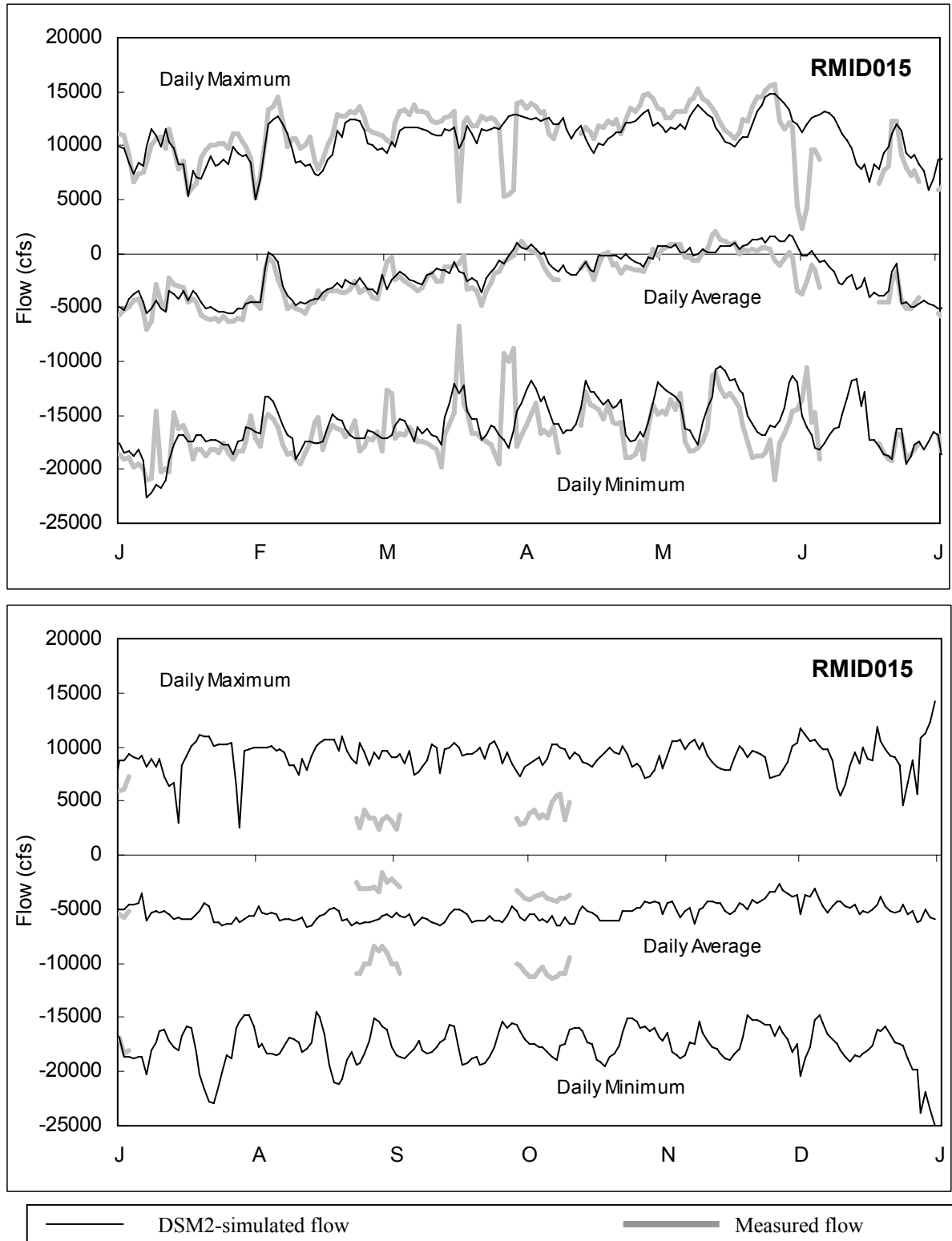


Figure 9-9-cont. Daily minimum, maximum, and average historical and DSM2-simulated flows, 2005



DSM2 Simulation of 2005 Hydrodynamics

In order to aid the interpretation of DSM2-simulated hydrodynamics, 2005 was partitioned into 20 periods which corresponded to times for which significant Delta inflows and exports were fairly constant and south Delta barrier configurations were unchanging. The 20 periods and their characteristics are shown in Table 9-3 below. The Delta hydrodynamics, as modeled by DSM2, are presented for each of the periods, excluding the periods of September 29-30 and November 8-13 which experienced transitions of multiple barrier installations or removals.

Table 9-3. Characteristics of intervals during 2005 for presentation of simulation results

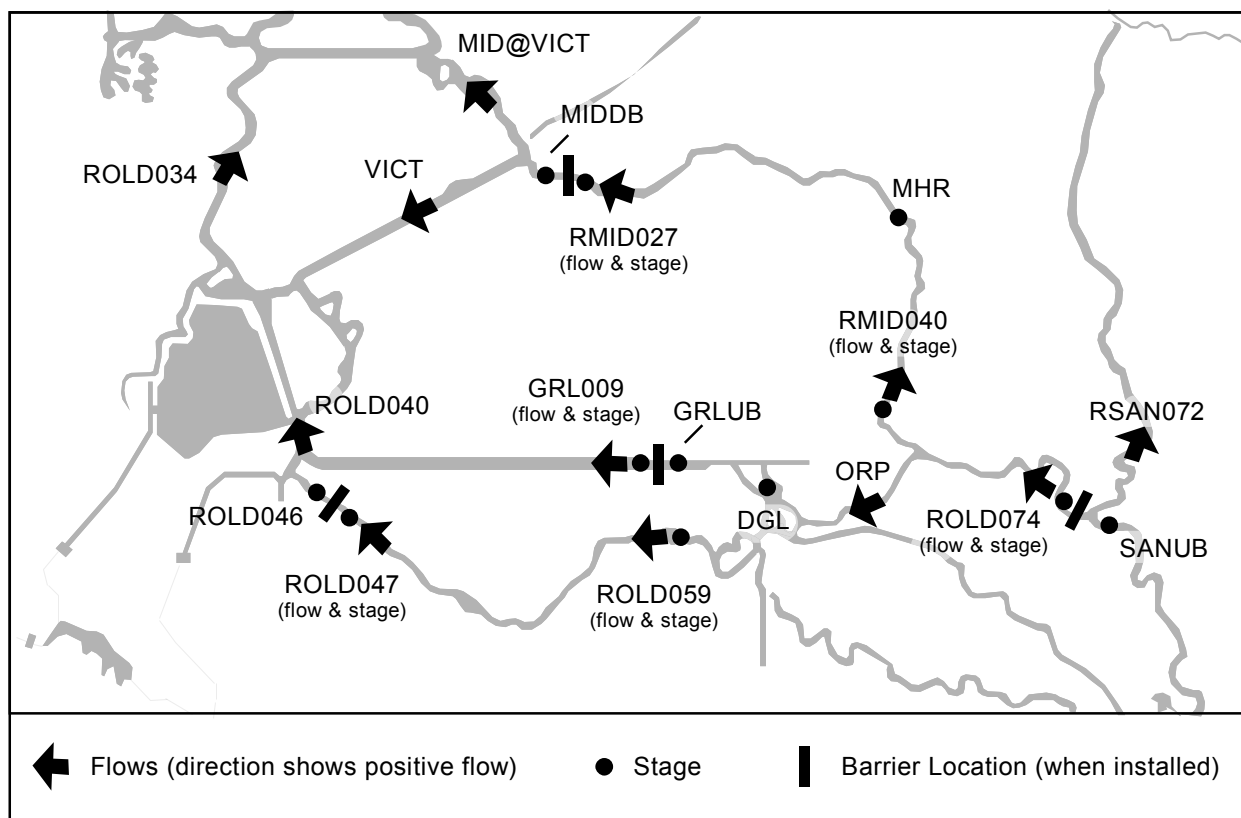
Period		Period Average Flows				Period Barrier Status			
		Sac R. + Yolo Bypass (cfs)	SJR (cfs)	DMC Pumping (cfs)	SWP Pumping (cfs)	MR	OR	GLC	ORH
JAN	1 - 31	33,208	5,008	4,217	7,783	--	--	--	--
FEB	1-28	24,031	5,370	3,889	4,987	--	--	--	--
MAR	1 - 15	25,291	6,995	4,359	3,081	--	--	--	--
	16 - 31	35,424	8,874	2,455	4,127	--	--	--	--
APR	1 - 17	24,788	11,656	2,209	5,299	--	--	--	--
	18 - 30	16,632	7,752	1,998	1,746	--	--	--	--
MAY	1 - 12	20,654	8,082	1,251	1,284	--	--	--	--
	12 - 19	41,763	8,806	912	1,568	IN	--	--	--
	20 - 25	83,615	12,420	928	1,299	IN	--	--	--
	26 - 31	47,300	14,755	1,042	3,389	IN	--	--	--
JUN	1 - 12	32,333	14,529	3,872	4,813	IN	IN	--	--
	12 - 30	26,506	7,480	4,364	5,520	IN	IN	--	--
JUL	1 - 12	19,208	6,135	4,377	7,098	IN	IN	--	--
	12 - 31	18,881	3,925	4,376	7,133	IN	IN	IN	--
AUG	1 - 31	17,951	2,755	4,408	7,057	IN	IN	IN	--
SEP	1 - 28	17,909	2,288	4,362	7,118	IN	IN	IN	--
OCT	1 - 31	14,640	2,335	4,335	6,316	IN	IN	IN	IN
NOV	1 - 7	12,264	2,189	4,291	4,840	IN	IN	IN	IN
	14 - 30	13,626	1,917	4,284	4,724	--	--	--	--
DEC	1 - 31	50,117	3,503	4,268	6,521	--	--	--	--

Hourly simulated stage and flow data for each period were used to generate data for box plots which graphically show period minimum, maximum, 25% quartile, 75% quartile, and average values. By typical sign convention, negative flow values correspond to upstream flow. The locations where box plots of stage and flow are presented are shown in Figure 9-10 with

arrows indicating assumed positive flow direction. The numerical values these graphs are based upon are presented in the appendix to this report.

The distributions of simulated stages and flow for each of the 20 intervals are shown in Figures 9-11 and 9-12. Stage results are presented upstream and downstream of each barrier location and flows are presented throughout the south Delta in order to convey the general circulation patterns. Some of the minimum stages and average flows from the distributions of data in Figures 9-11 and 9-12 are shown in Figure 9-13 which graphically presents the flow circulation and minimum water levels caused by the installation of the south Delta barriers in 2005.

Figure 9-10. Locations where simulated Delta stages and flows for 2005 are presented



Discussion

The installation of the temporary barriers in 2005 significantly altered stages and flows in the south Delta. When the barrier in Middle River was installed in mid May, minimum water levels immediately upstream of the barrier were raised approximately 1-½ feet. This improvement decreased moving upstream until it essentially was eliminated at the junction of Old River. Thus, the effects on water levels due to the installation of the Middle River barrier alone were essentially restricted to Middle River. The installation of the Old River barrier at the beginning of June in 2005 raised minimum water levels immediately upstream of the barrier approximately 1-½ feet, an improvement which decreased further upstream. The Old River barrier had no apparent impact to water levels in Middle River or Grant Line Canal. For the period of June 1, 2005 to July 12, 2005, only the barriers at Middle River and Old River were installed. During this time, these barriers' primary impact was significantly raising water levels immediately upstream, an effect

which diminished further upstream until becoming negligible in Grant Line Canal. The main circulation patterns in the south Delta during this period were only modestly altered by the two barriers since the flow split from the San Joaquin River down the head of Old River and then the subsequent flow down Grant Line Canal weren't strongly affected.

The installation of the Grant Line Canal barrier in mid July raised minimum water levels in Grant Line Canal upstream of the barrier approximately 2-½ feet and levels in Middle River and Old River an additional ½ feet. Also, circulation patterns were altered as shown by a reduced split of San Joaquin River flow down the head of Old River to less than 50% and less of a portion of this water then passing down Grant Line Canal and more going down Old River. Thus, the full impact on minimum water levels and changed flow patterns was not realized until the Grant Line Canal barrier was installed. In general, the installation of the temporary barriers also resulted in reduced tidal variation in flows near the barriers, a trend once again made more pronounced in Old and Middle Rivers with the installation of the barrier in Grant Line Canal. Each of the barriers still allowed some downstream flow, while both upstream and downstream flow was suppressed in the channels upstream of each barrier site.

The installation of the notched barrier at the head of Old River in October significantly reduced the amount of San Joaquin River flowing down Old River and Grant Line Canal. Due to a combination of this change and lower consumptive use in south Delta channels in October and November, average flow in Old River was in the upstream direction from the barrier site towards Tracy Road. This is consistent with simulations of other historical periods when all barriers are simultaneously installed; that is, net reverse flow in Old River is induced when both the agriculture and head of Old River barriers are in. Fingerprinting and particle tracking simulations have shown that under these circumstances, water originating from the Sacramento River may reach the Old River at Tracy Road location.

Figure 9-11. Box Plots showing distribution of DSM2-simulated stages for various periods during 2005
periods during 2005.

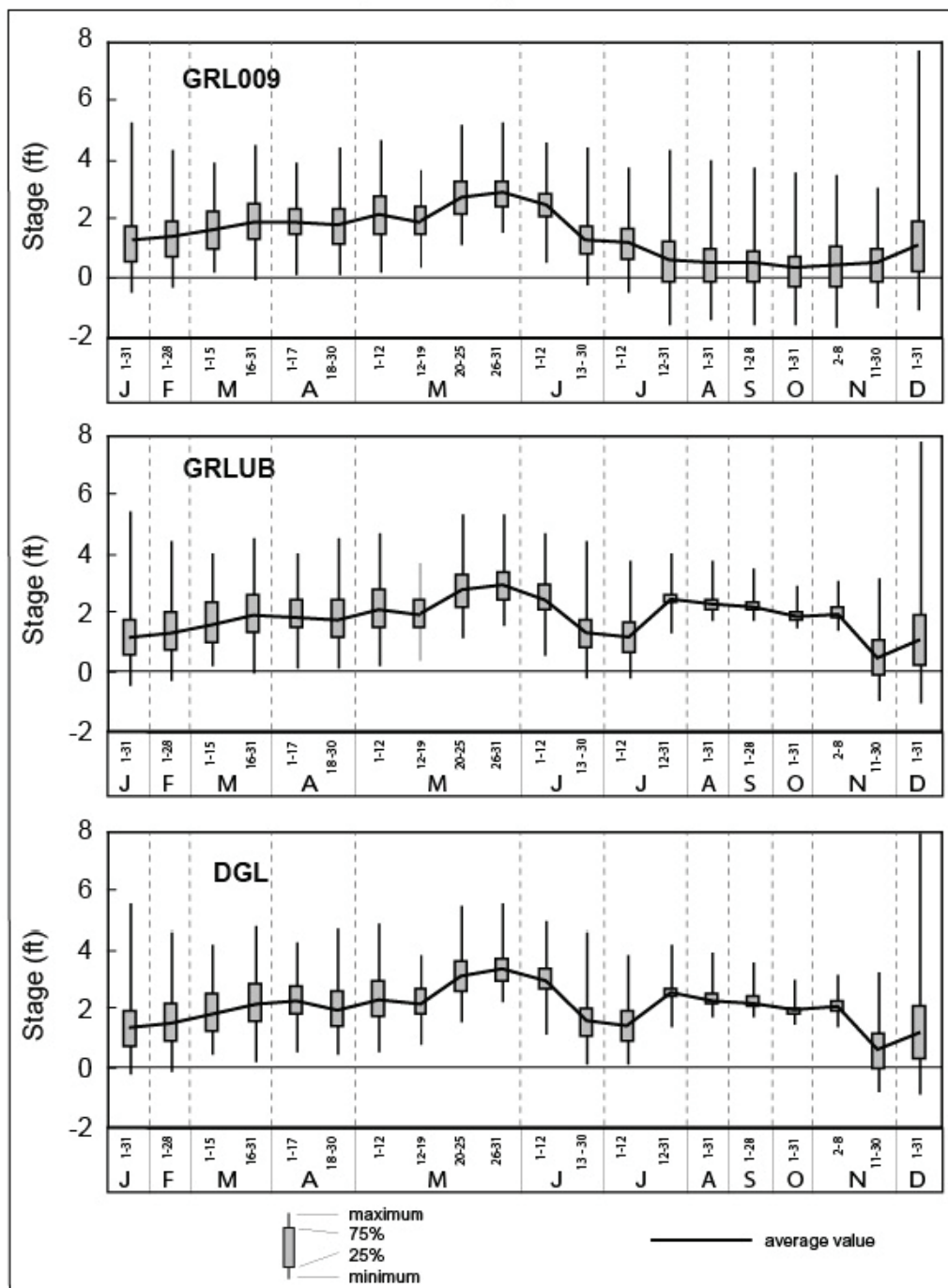


Figure 9-11 – cont. Box Plots showing distribution of DSM2-simulated stages for various periods during 2005

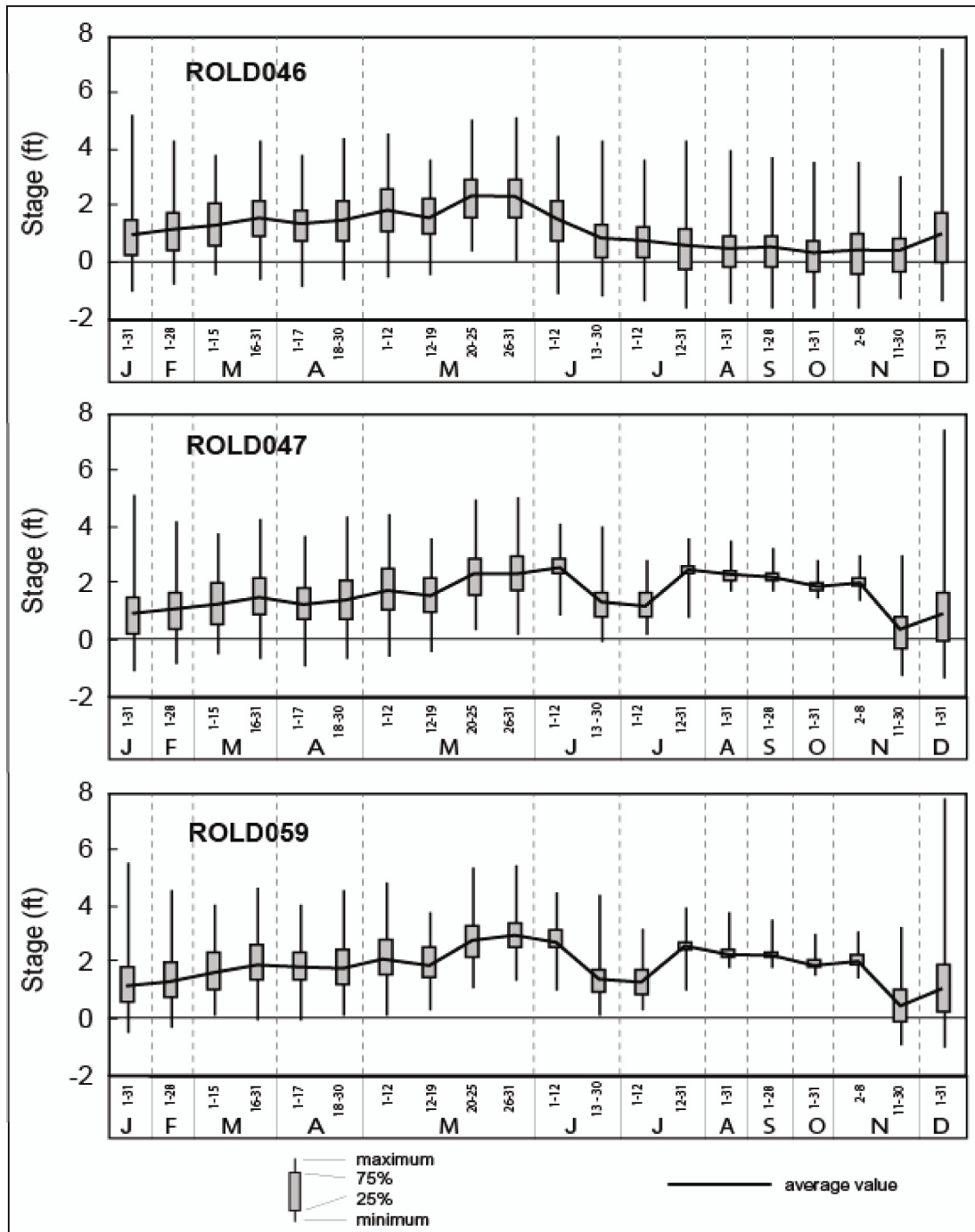


Figure 9-11 – cont. Box Plots showing distribution of DSM2-simulated stages for various periods during 2005

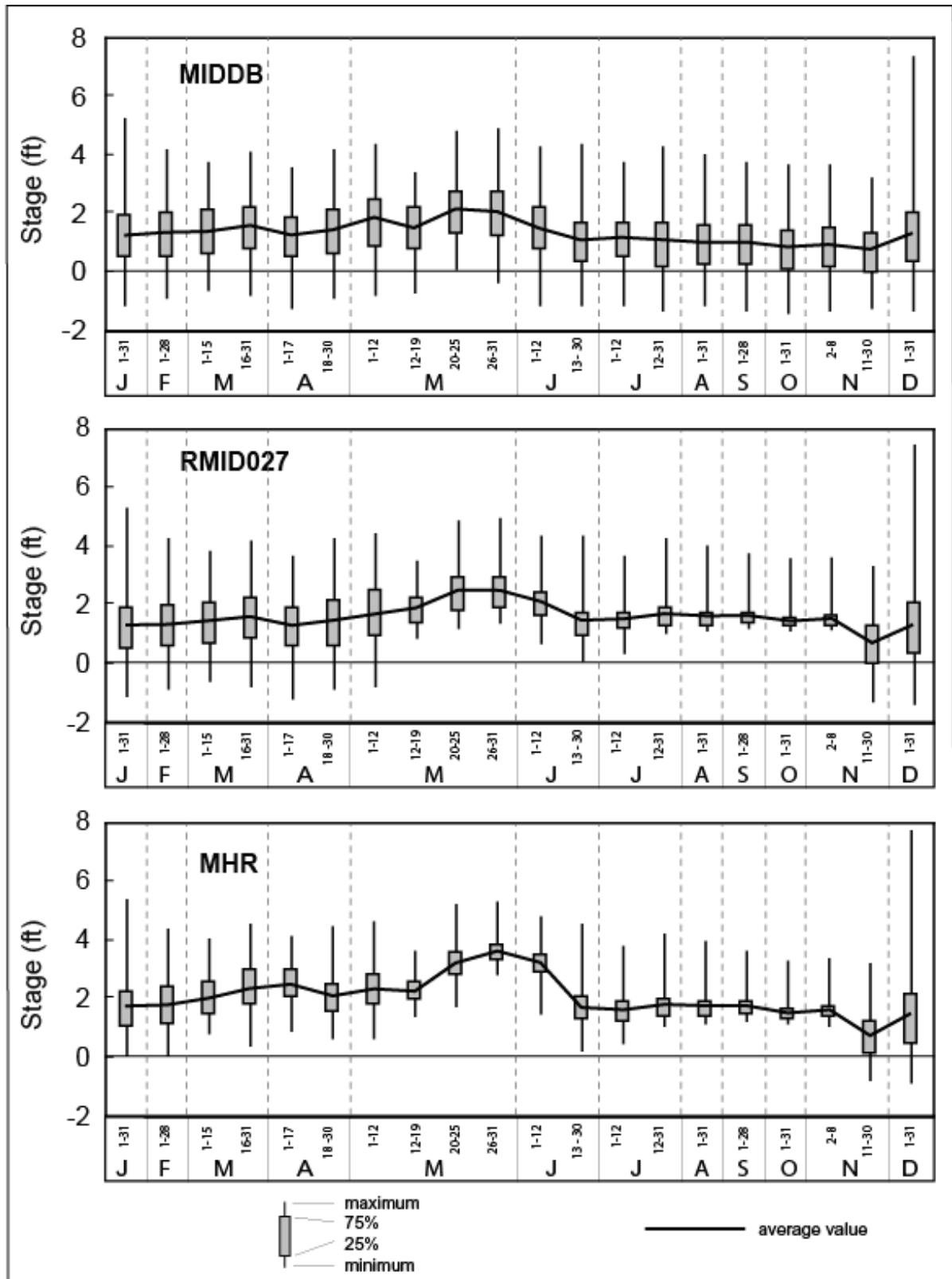


Figure 9-11 – cont. Box Plots showing distribution of DSM2-simulated stages for various periods during 2005

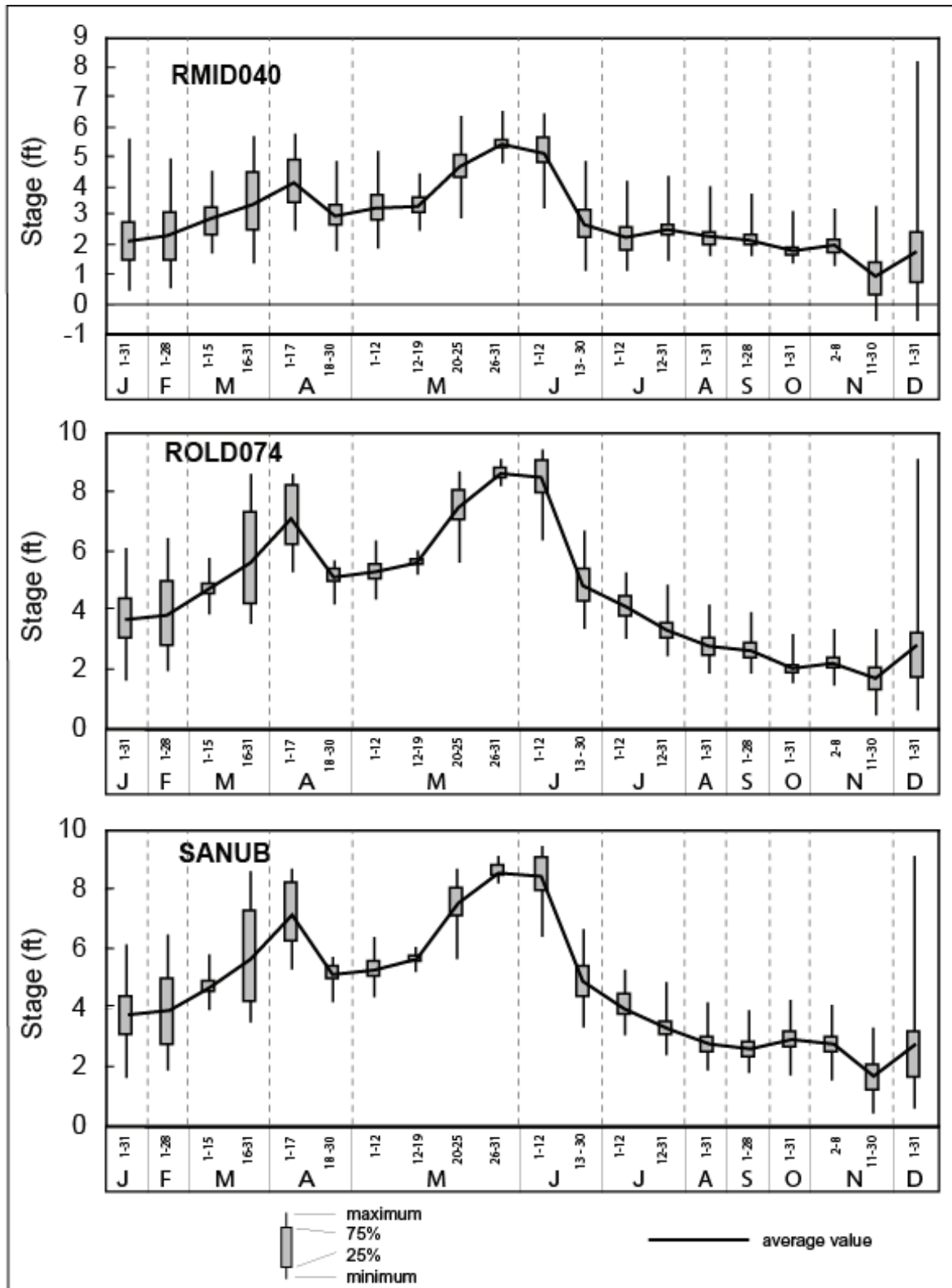


Figure 9-12. Box Plots showing distribution of DSM2-simulated flows for various periods during 2005

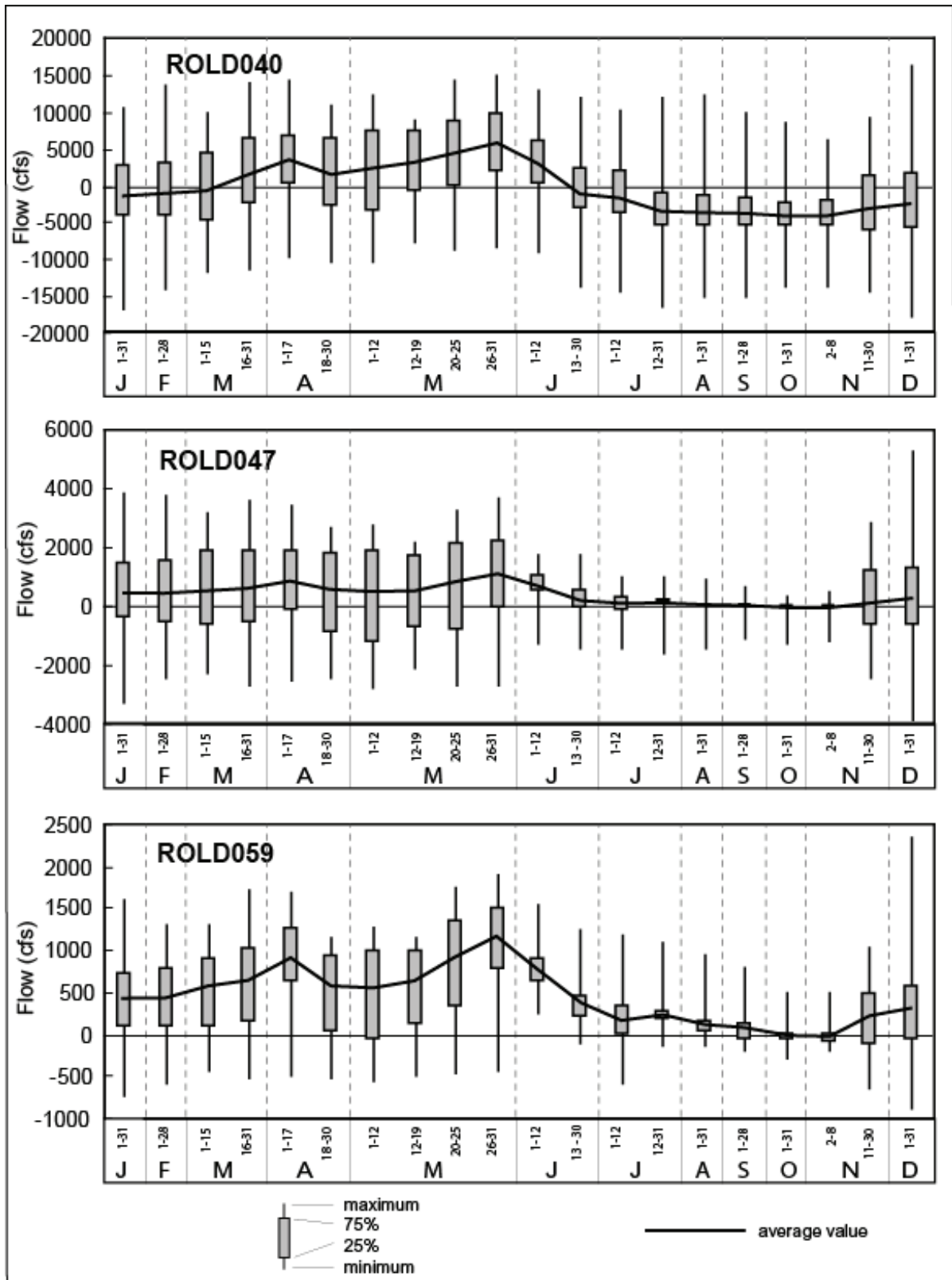


Figure 9-12 – cont. Box Plots showing distribution of DSM2-simulated flows for various periods during 2005

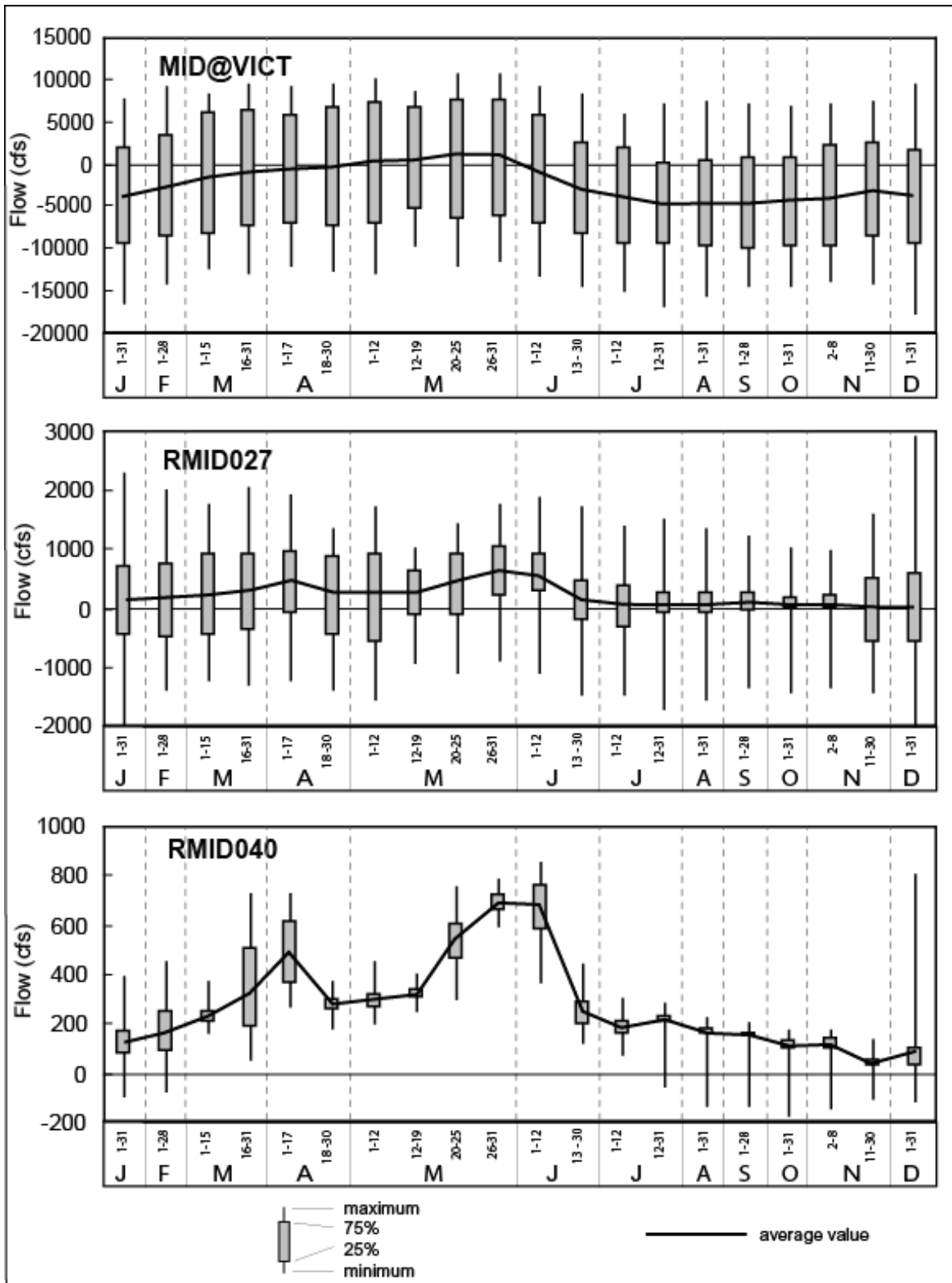


Figure 9-12 – cont. Box Plots showing distribution of DSM2-simulated flows for various periods during 2005

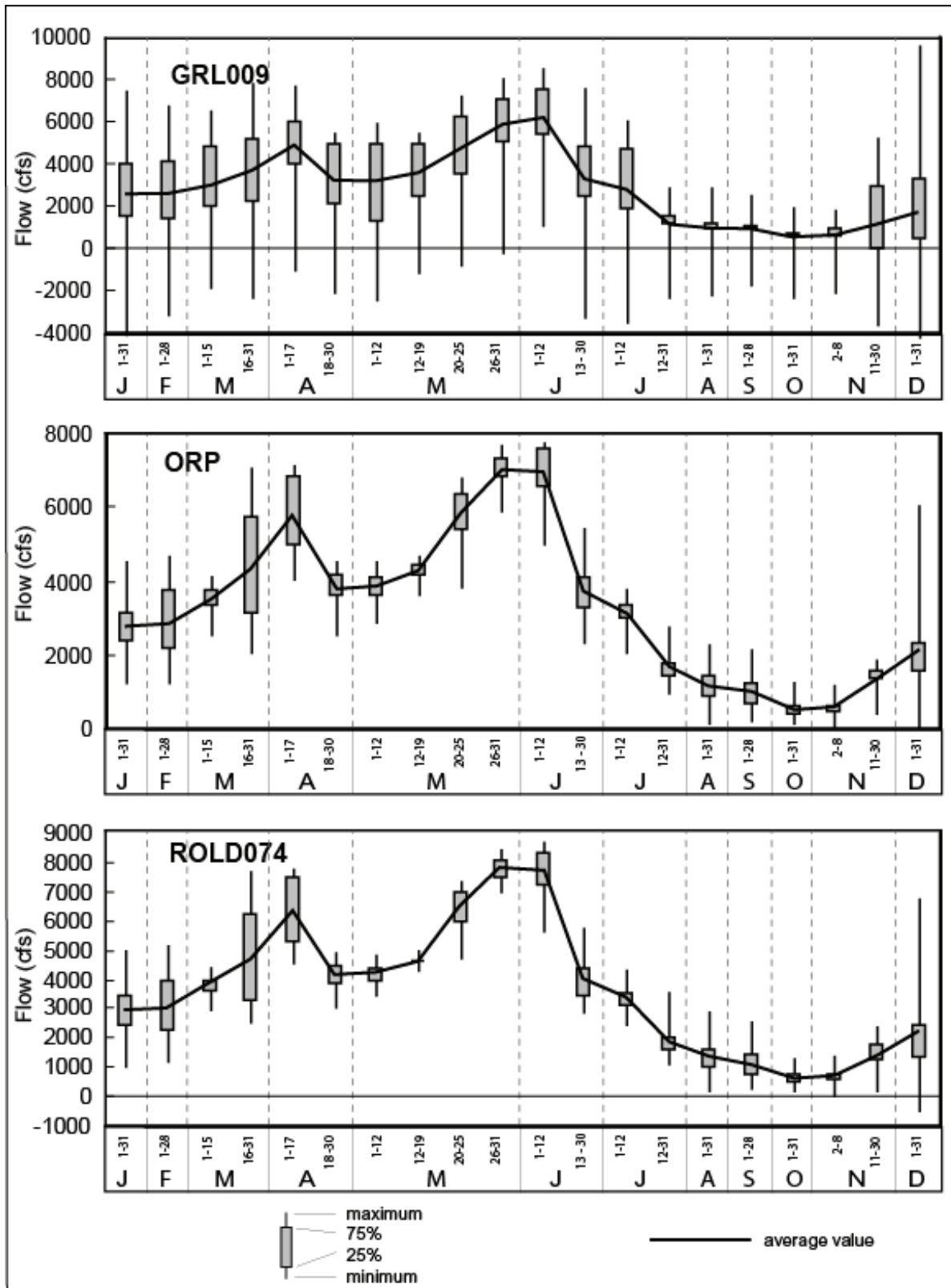


Figure 9-12 – cont. Box Plots showing distribution of DSM2-simulated flows for various periods during 2005

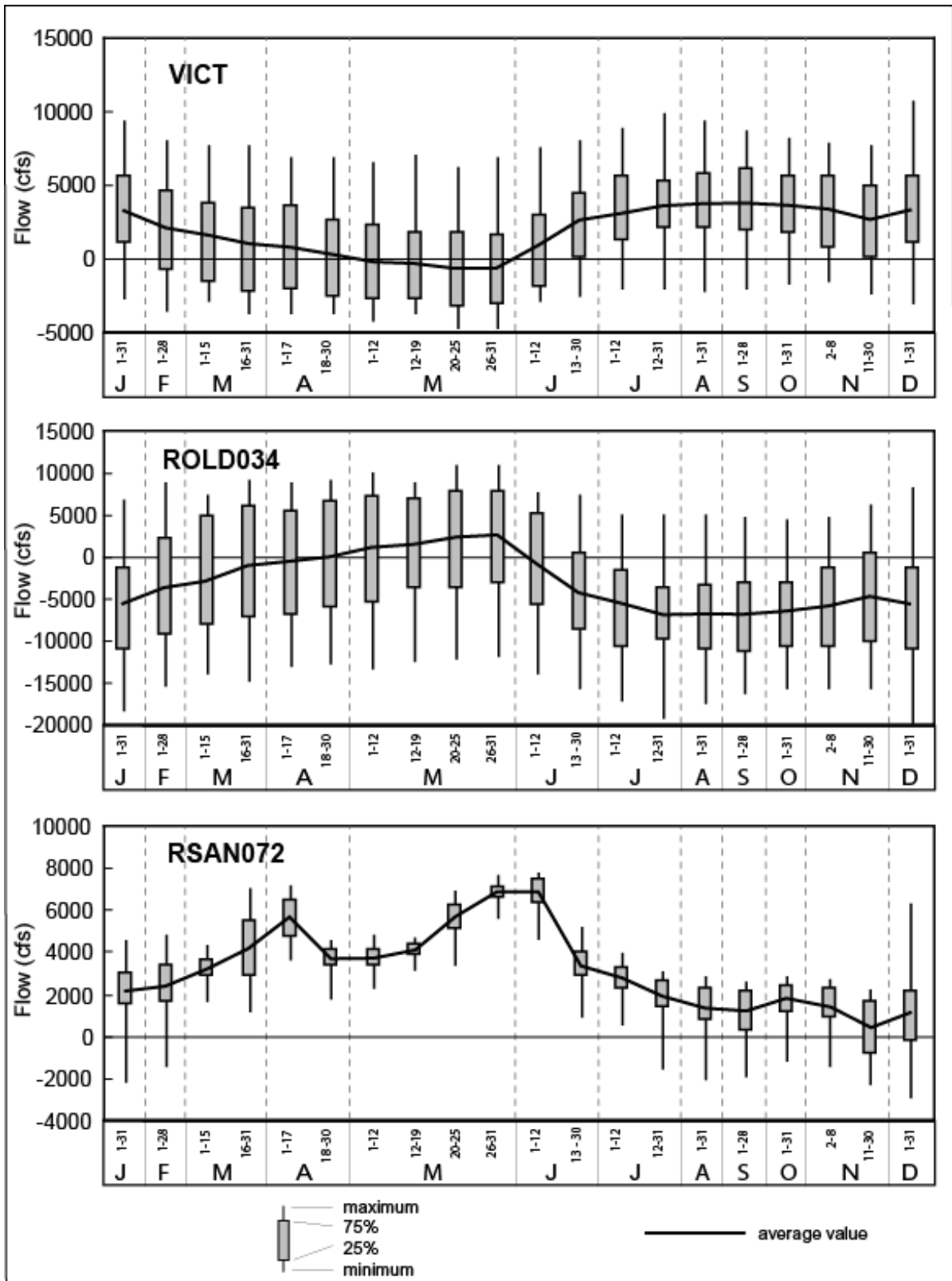


Figure 9-13. DSM2-simulated average flow patterns and minimum stages for 2005

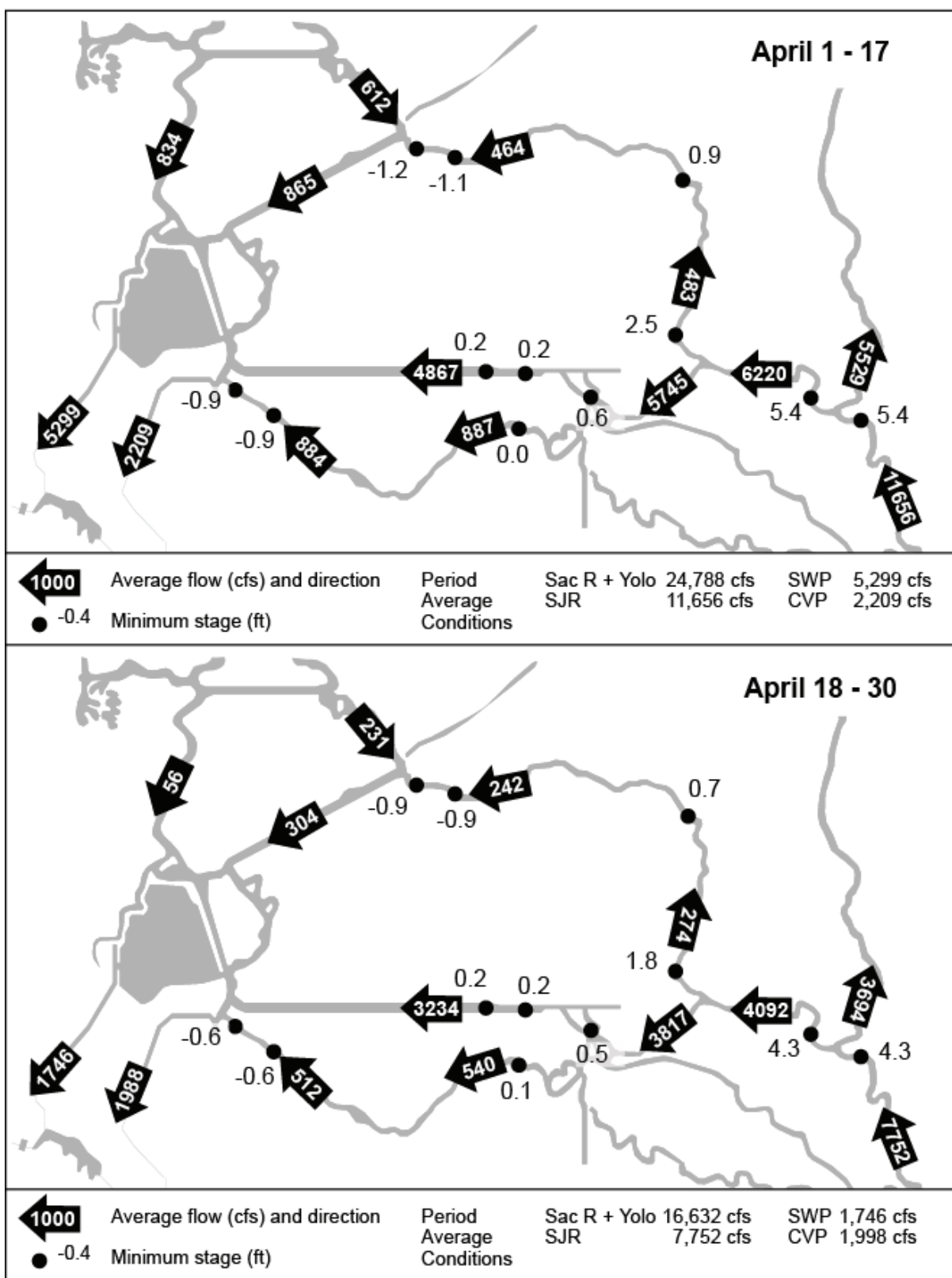


Figure 9-13 – cont. DSM2-simulated average flow patterns and minimum stages for 2005

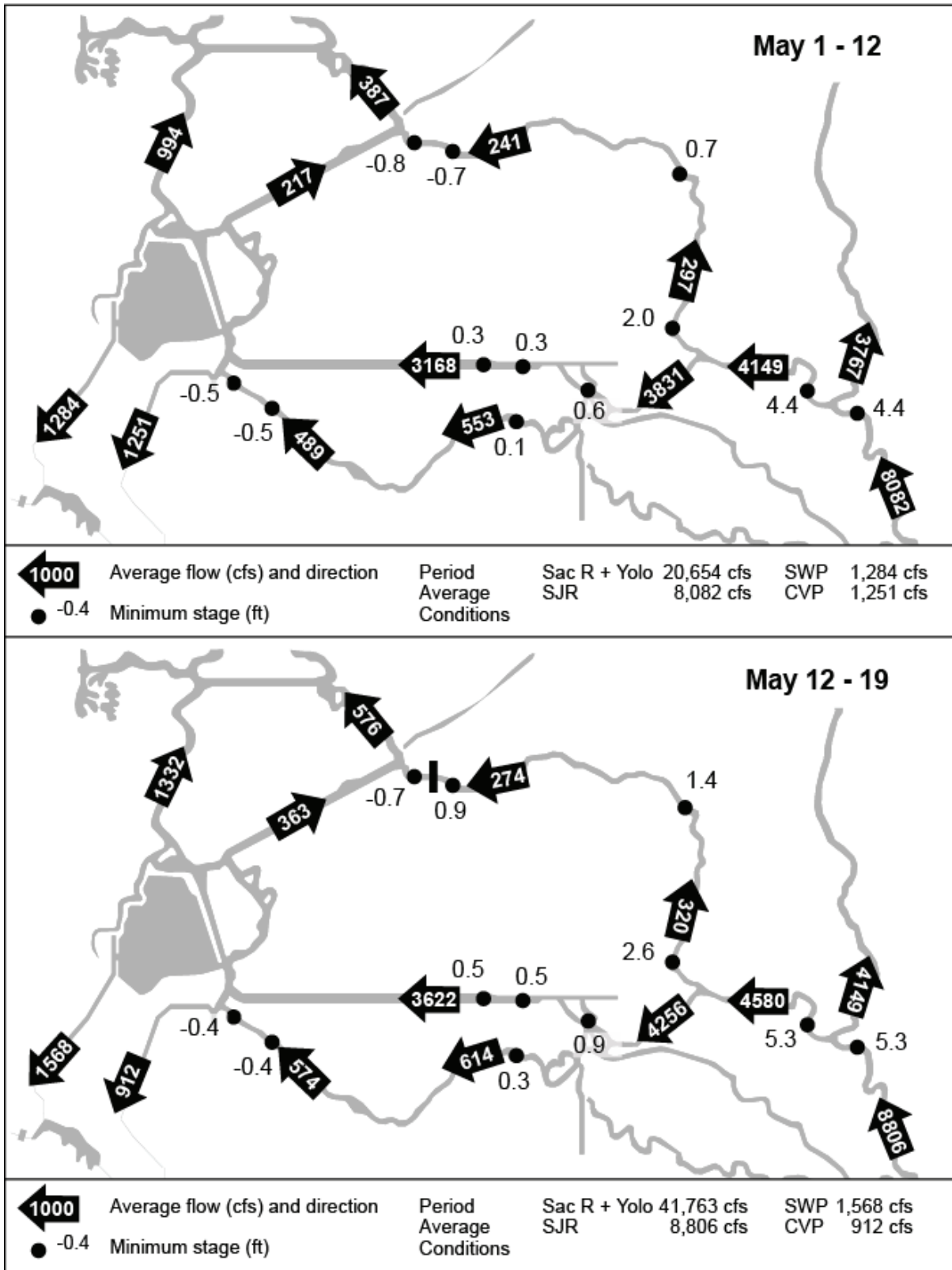


Figure 9-13 – cont. DSM2-simulated average flow patterns and minimum stages for 2005

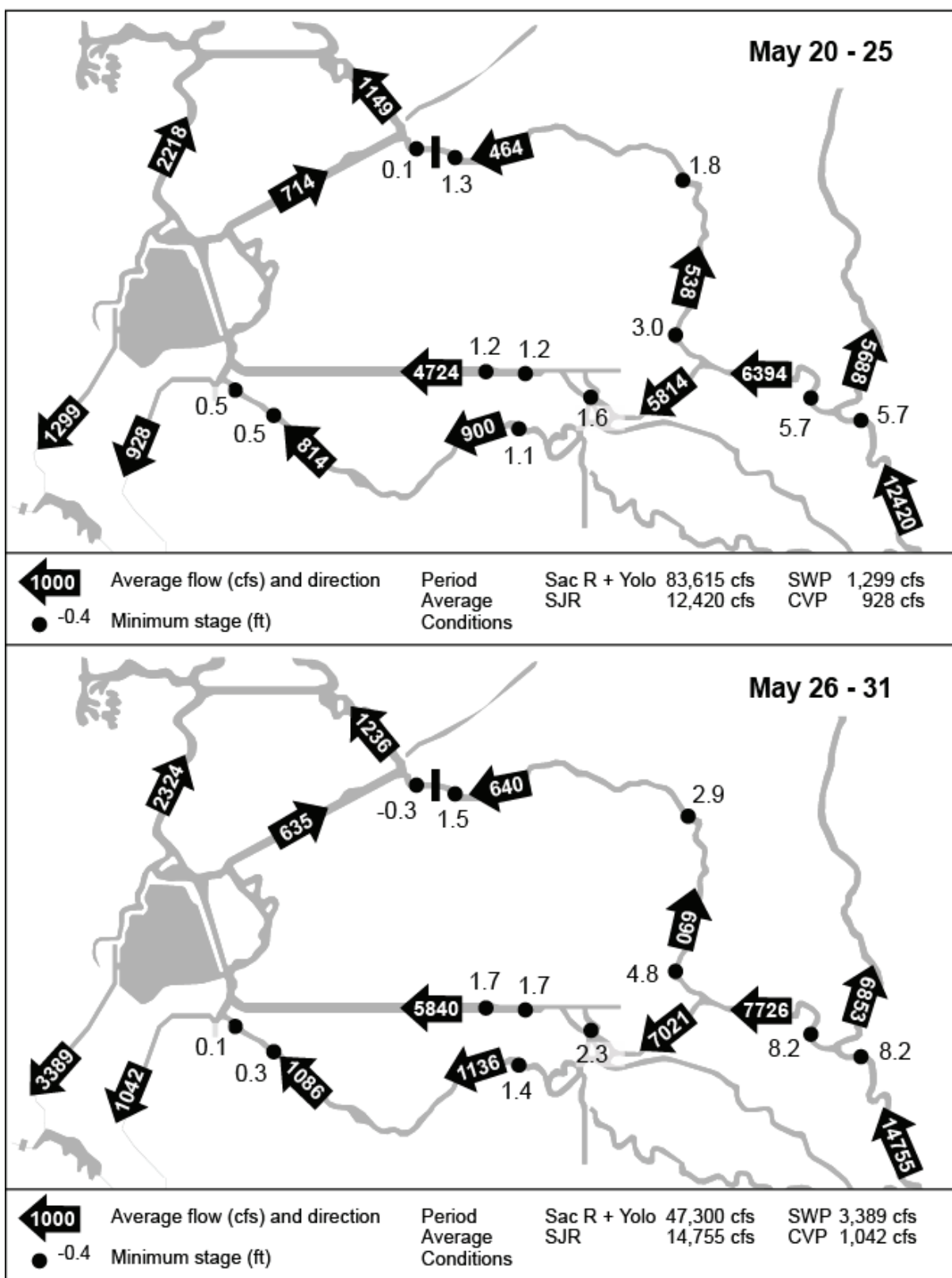


Figure 9-13 – cont. DSM2-simulated average flow patterns and minimum stages for 2005

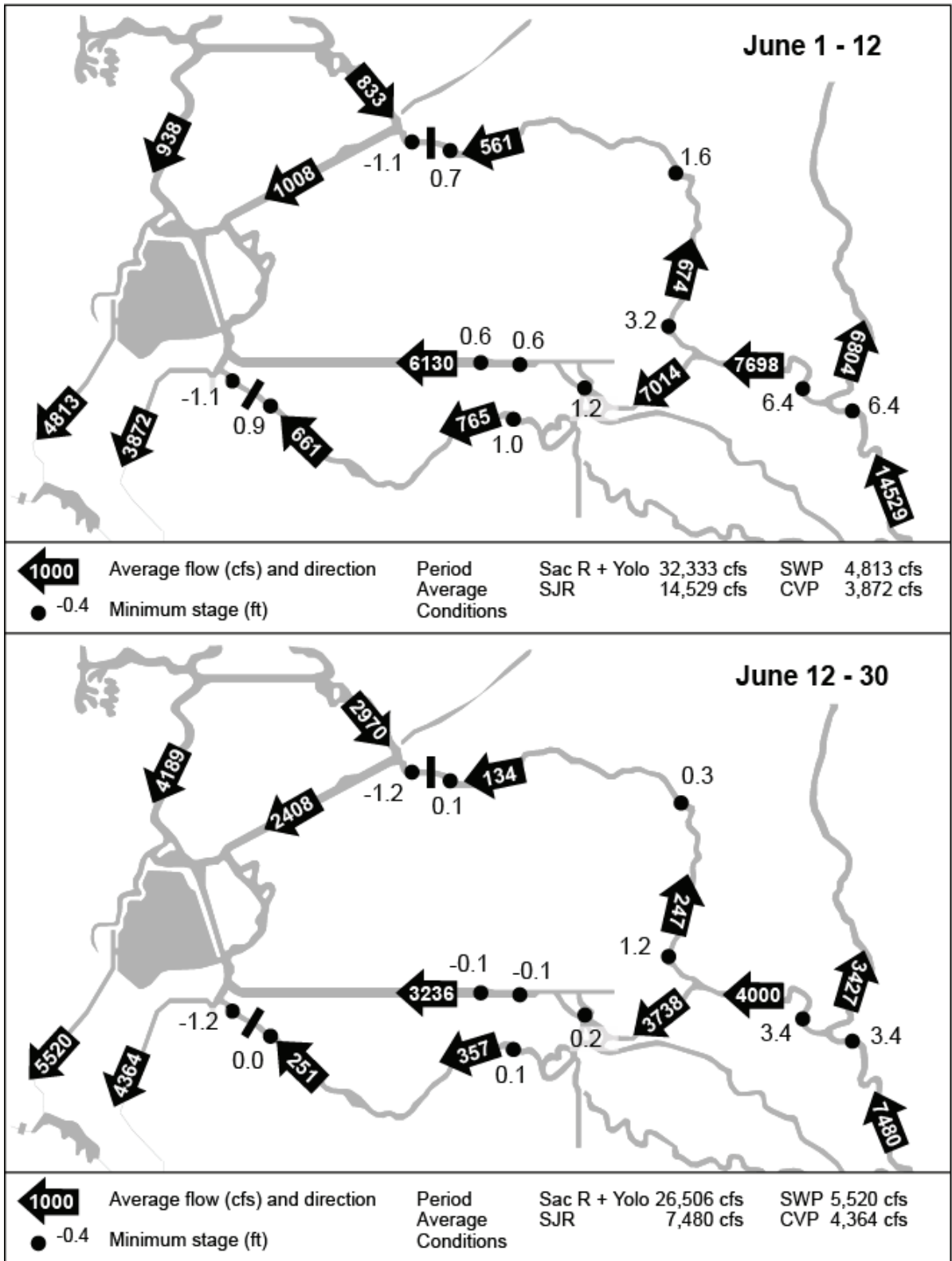


Figure 9-13 – cont. DSM2-simulated average flow patterns and minimum stages for 2005

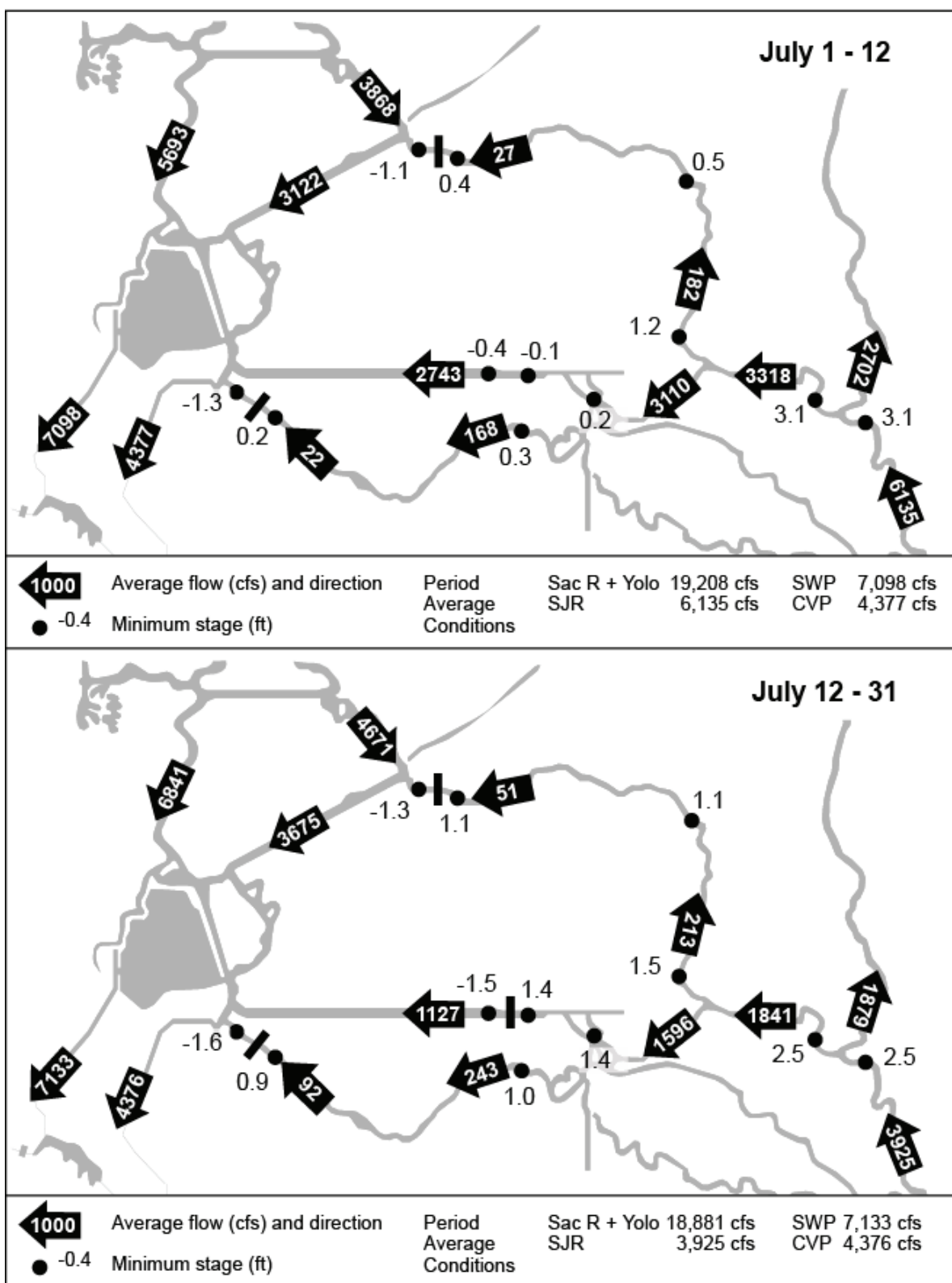


Figure 9-13 – cont. DSM2-simulated average flow patterns and minimum stages for 2005

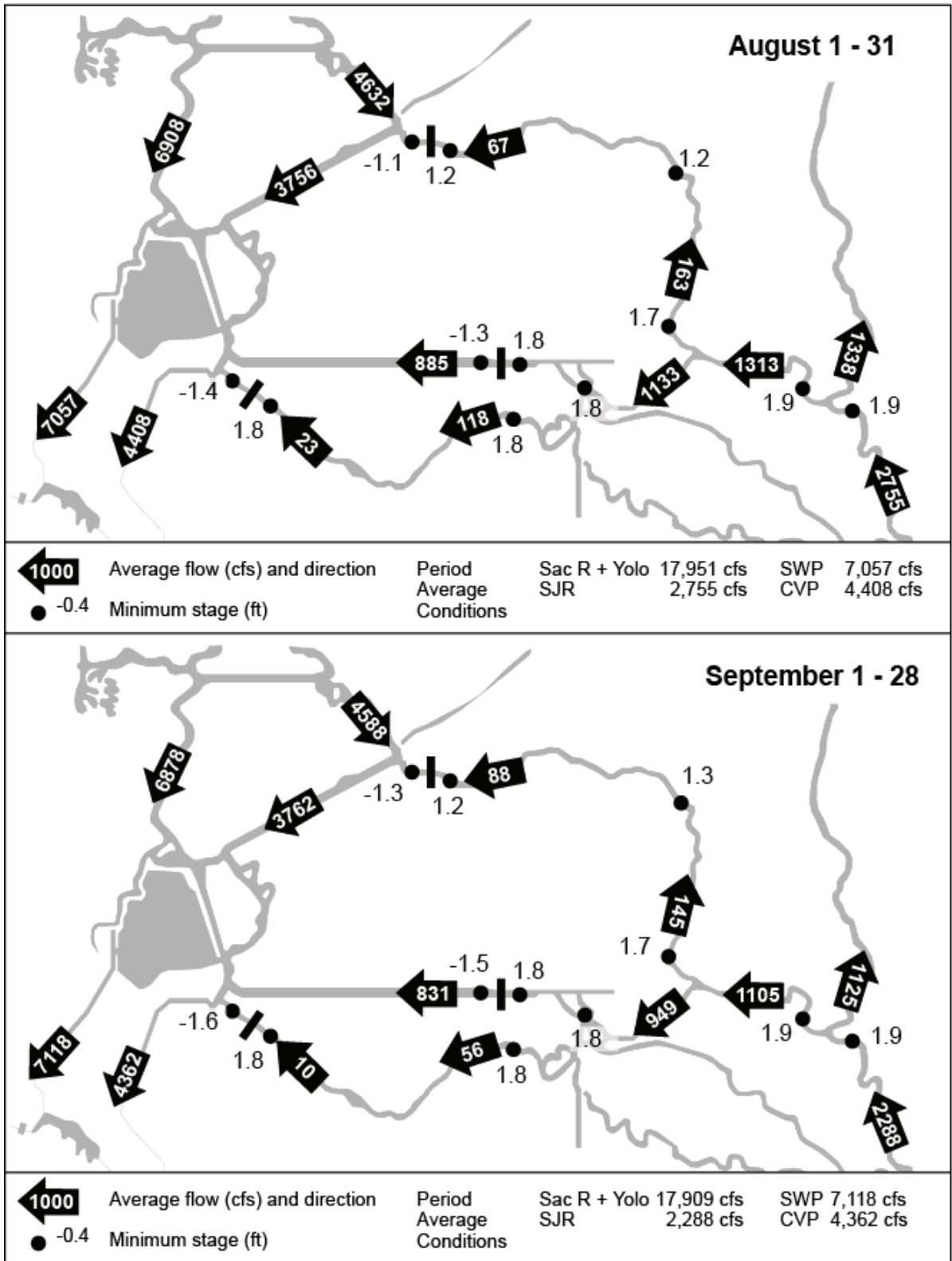


Figure 9-13 – cont. DSM2-simulated average flow patterns and minimum stages for 2005

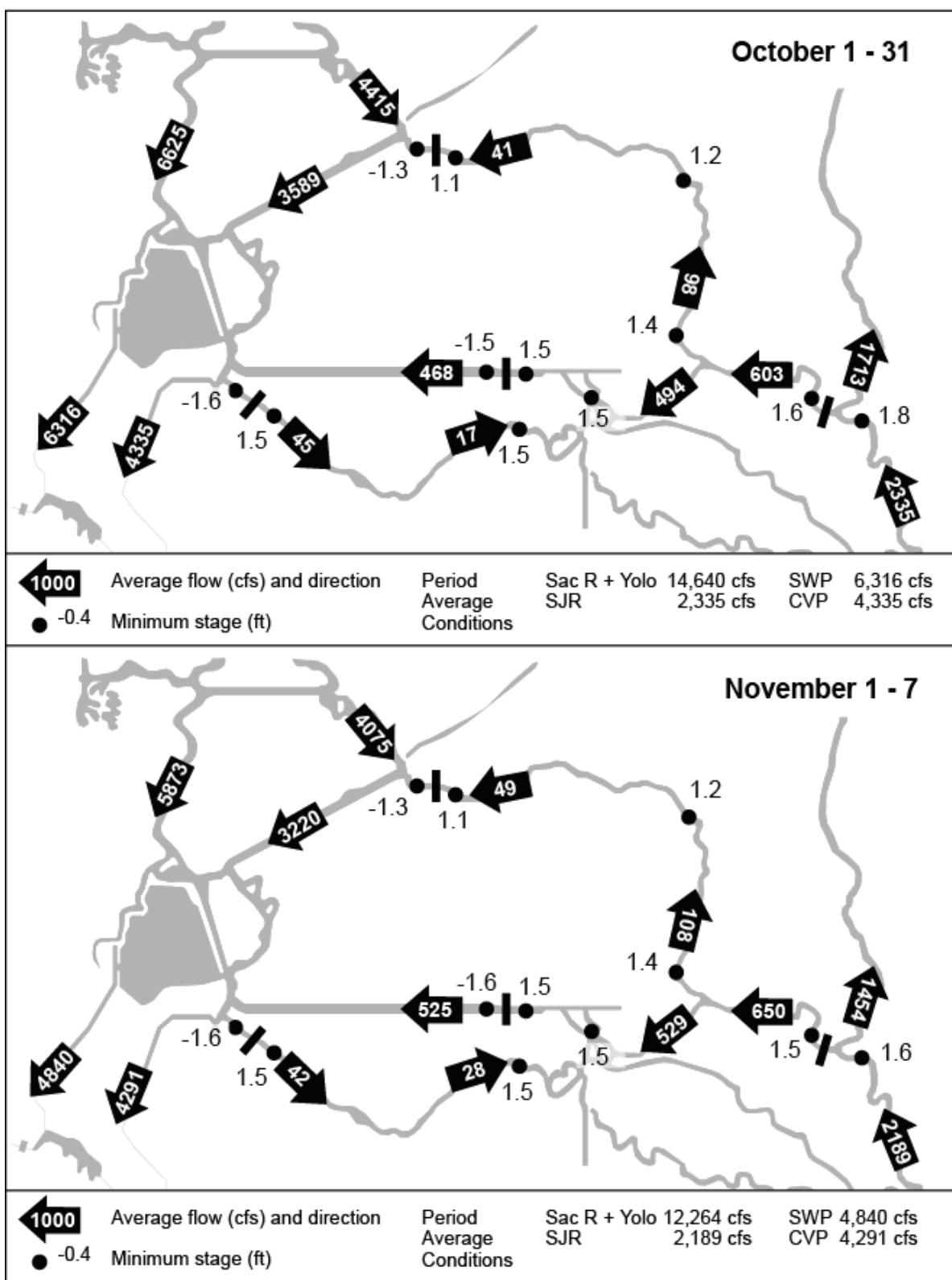
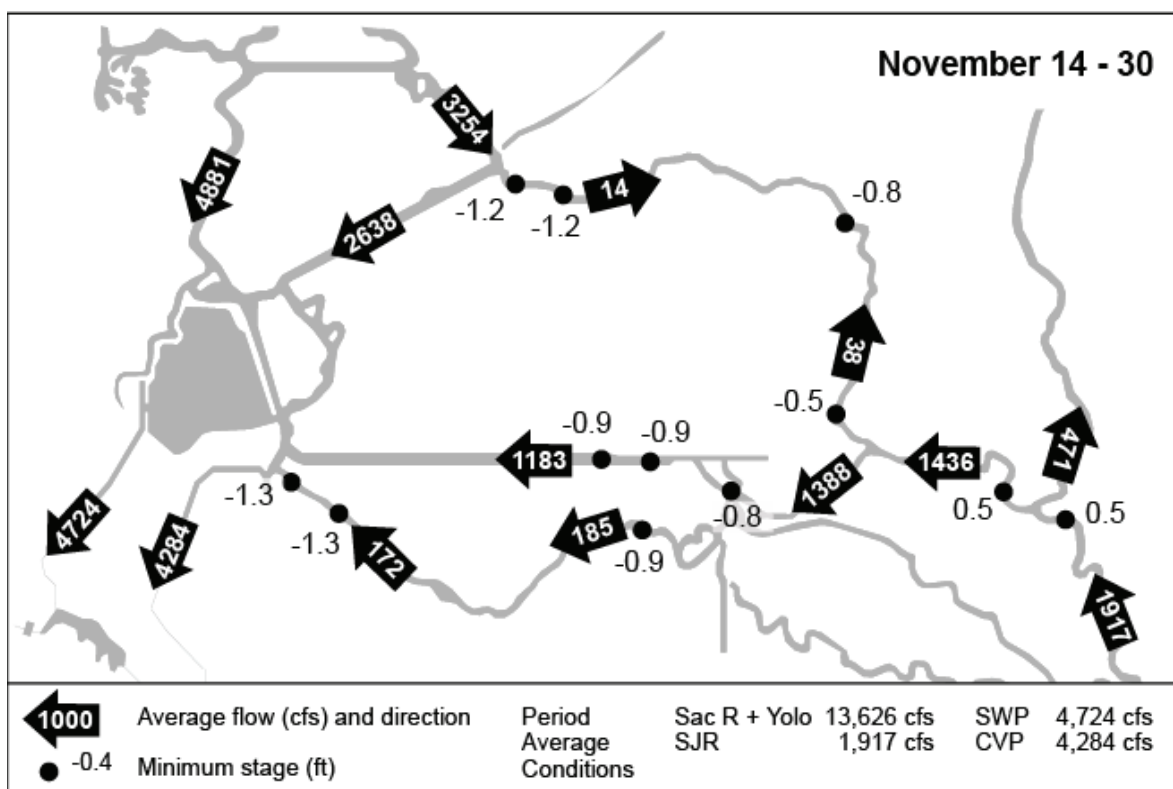


Figure 9-13 – cont. DSM2-simulated average flow patterns and minimum stages for 2005



Appendix A. Chinook Salmon Survival Investigations

Figure A-1. Water temperature monitoring locations

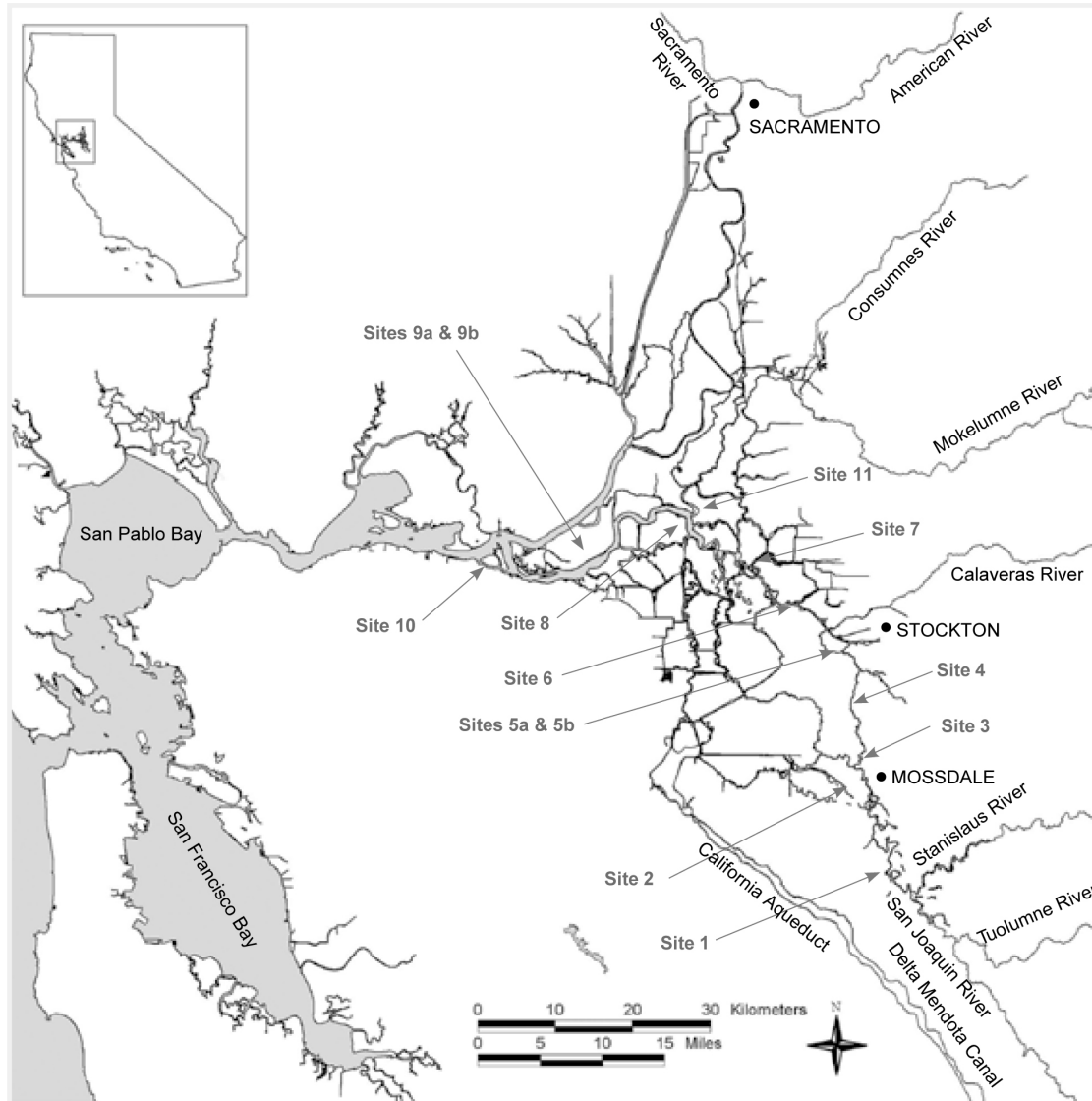


Table A-1. VAMP 2005 water temperature monitoring

Site #	Temperature Monitoring Location	Latitude	Longitude	Distance from Durham Ferry (mi)	Date Deployed	Date Retrieved	Notes
	Merced River Hatchery - 1			n/a	April 4	May 4	In river May 2 at Durham Ferry
	Merced River Hatchery - 2			n/a	April 4	May 11	In river May 9 at Durham Ferry
1	Durham Ferry	N 37 41.381	W 121 15.657	n/a	April 15	June 15	3 foot depth
2	Mossdale	N 37 47.180	W 121 18.425	11.2	April 15	June 15	3 foot depth
3	Dos Reis	N 37 49.808	W 121 18.665	16.4	April 15	-	Unable to locate logger
4	DWR Monitoring Station	N 37 51.869	W 121 19.376	19.4	April 15	-	Unable to locate logger
5a	Confluence – Top	N 37 56.818	W 121 20.285	26.5	April 15	June 15	logger was dewatered – unable to use data
5b	Confluence- Bottom	N 37 56.818	W 121 20.285	26.5	April 15	June 15	logger located on bottom.
6	Downstream of Channel Marker 30	N 37 59.776	W 121 25.569	33.3	April 15	June 15	3 foot depth
7	1/2 mile Upstream of Channel Marker 13	N 38 01.940	W 121 28.769	37.3	April 15	June 15	3 foot depth
8	Downstream of Channel Marker 36	N 38 04.522	W 121 34.413	44.7	April 15	June 15	3 foot depth
9	Jersey Point USGS Gauging Station - Top	N 38 03.172	W121 41.637	56.0	April 15	June 15	3 foot depth
10	Chippis Island	N 38 03.084	W 121 55.463	71.5	April 15	-	Unable to locate logger
11	Mokelumne River-	N 38 06.334	W 121 34.213	40.0	April 15	June 15	3 foot depth

Figure A-2a. Water Temperature Monitoring: Merced River Fish Hatchery to Durham Ferry

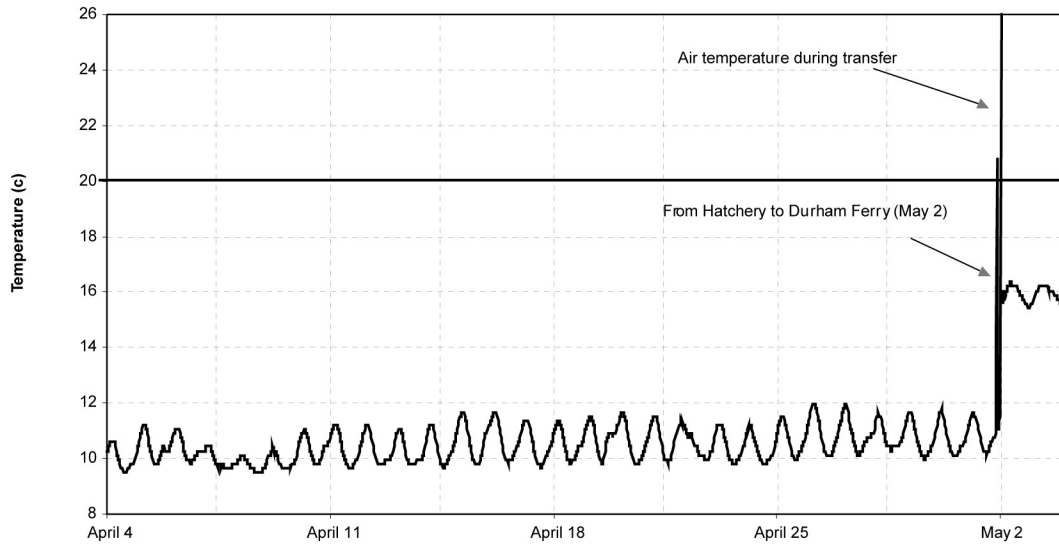


Figure A-2b. Water Temperature Monitoring: Merced River Fish Hatchery to Durham Ferry

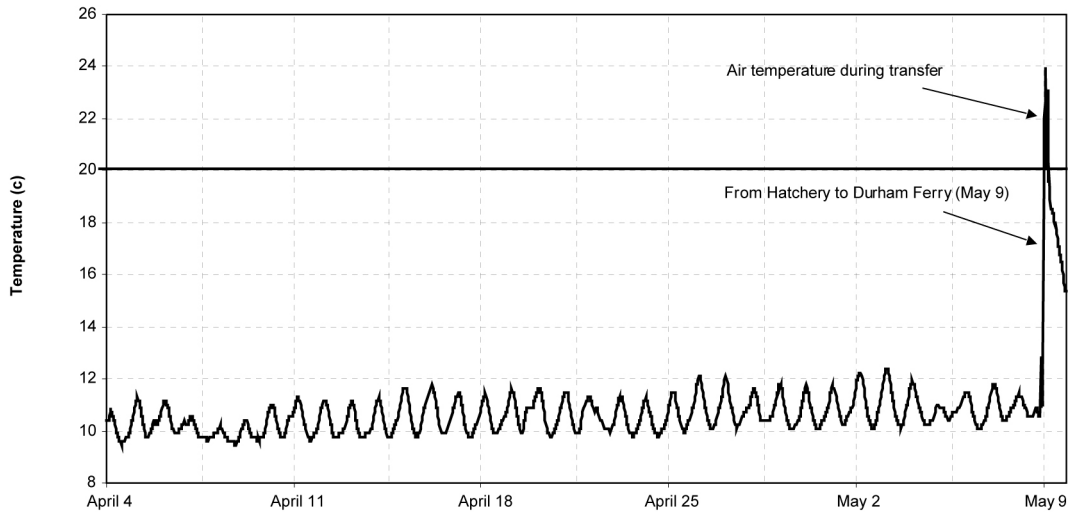


Figure A-3. Water Temperature Monitoring: Site 1 Durham Ferry

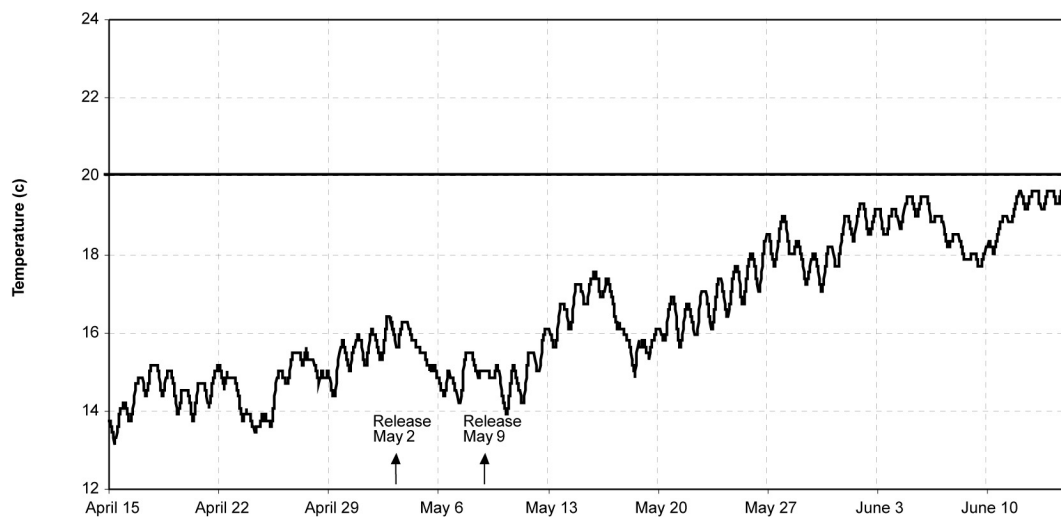


Figure A-4. Water Temperature Monitoring: Site 2 Mossdale

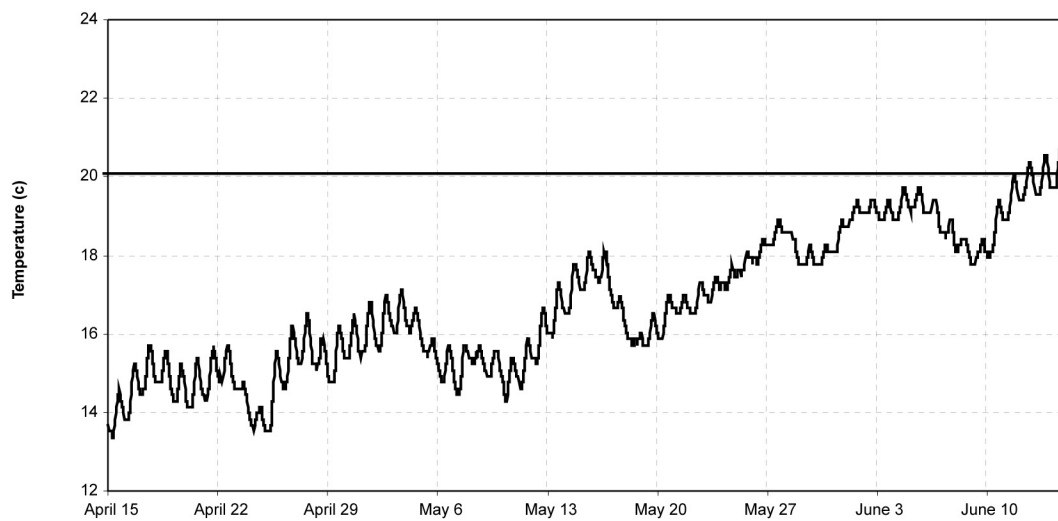


Figure A-5. Water Temperature Monitoring: Site 5b - Confluence-Bottom

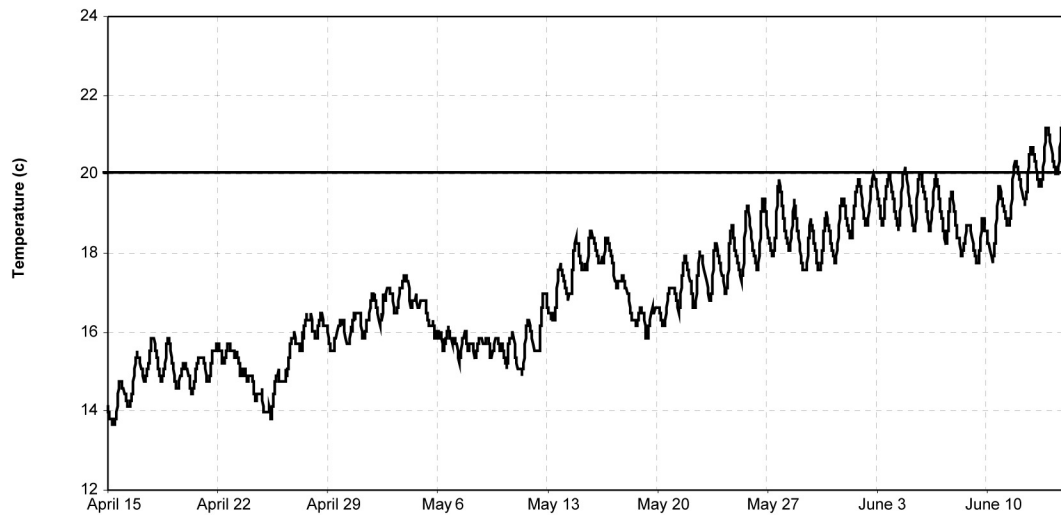


Figure A-6. Water Temperature Monitoring: Site 6 - Downstream of Channel Marker 30

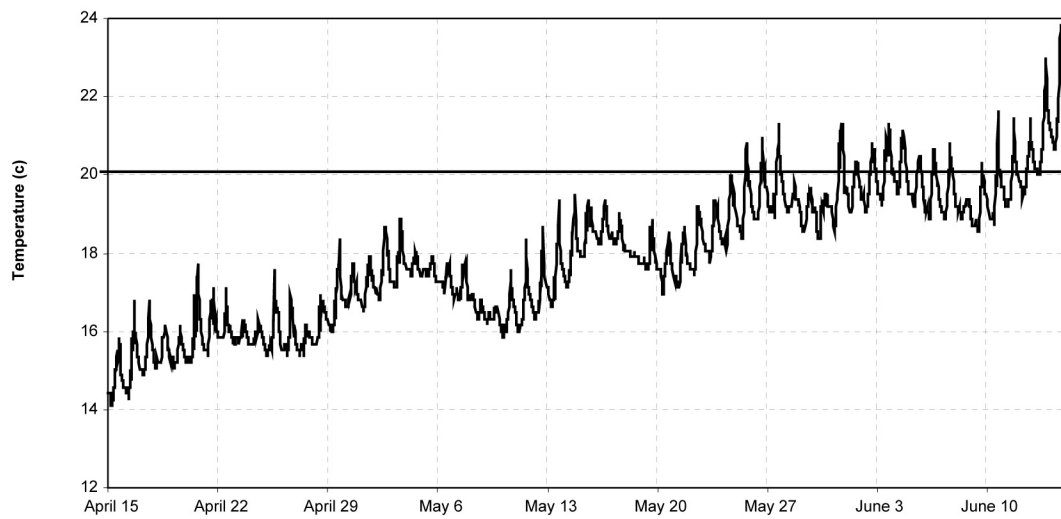


Figure A-7. Water Temperature Monitoring: Site 7 - 1/2 Mile Upstream of Channel Marker 13

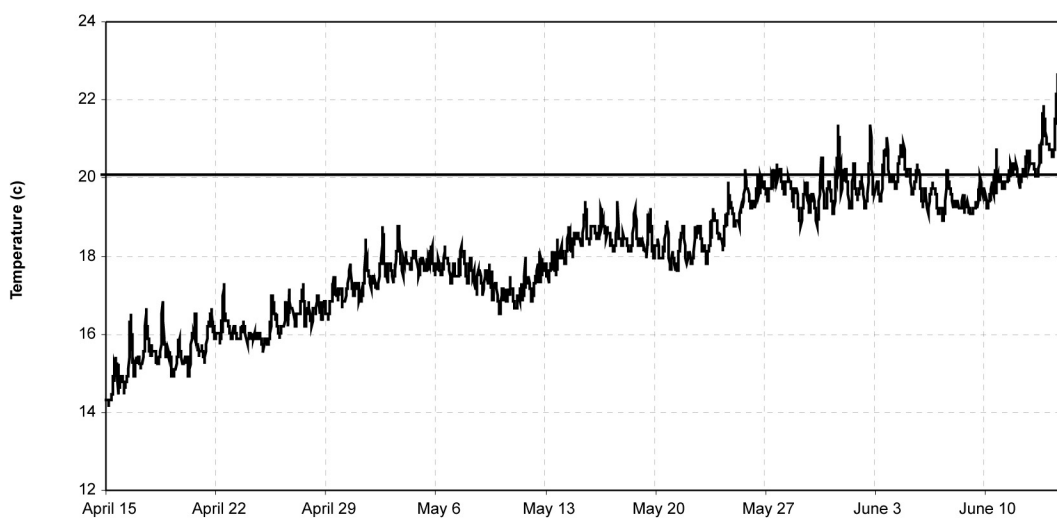


Figure A-8. Water Temperature Monitoring: Site 8 - Downstream of Channel Marker 36

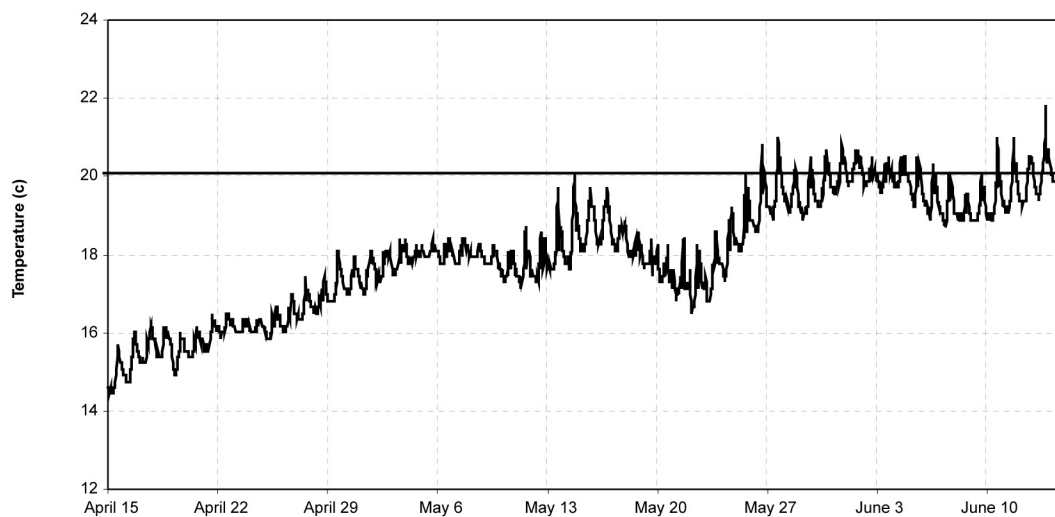


Figure A-9. Water Temperature Monitoring: Site 9 - USGS Gauging Station at Jersey Point - Top

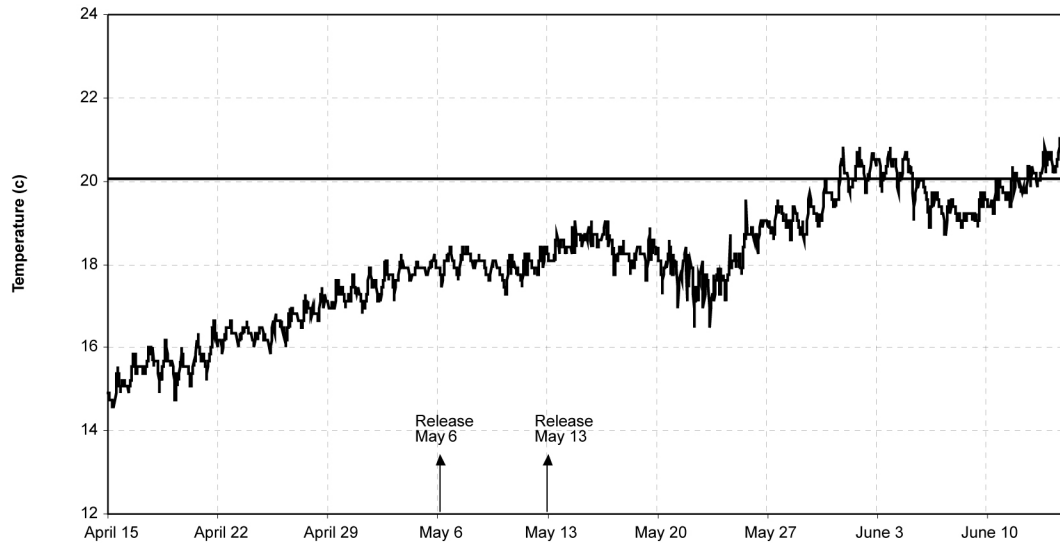


Figure A-10. Water Temperature Monitoring: Site 11 - Mokelumne River - Lighthouse Marina

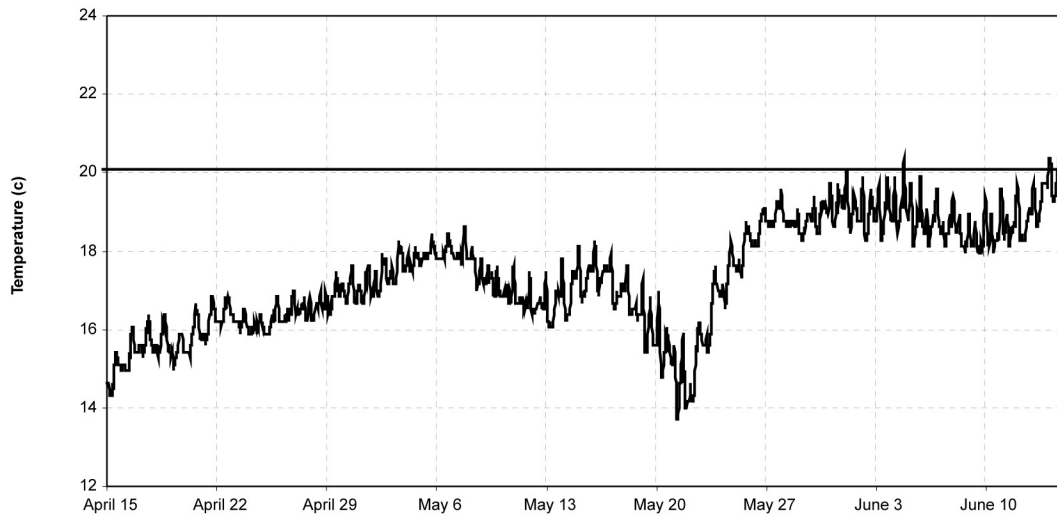


Table A-2. Salmon smolt condition post transport, immediately after release

Release Site	Examination Date	Mean Fork Length (mm)	Mean Weight (g)	Vigor (%)	Mean Scale Loss (%)	Normal Body Color (%)	Fin Hemorrhaging (%)	Normal Eye Quality (%)	Normal Gill Color (%)	Complete Adclip (%)	% Correct Tag Code *
Durham Ferry	5/2/05	85	7	100	3	100	0	100	100	90	100
Dos Reis	5/3/05	86	7	100	3	100	0	100	100	88	100
Jersey Point	5/6/05	83	7	100	3	100	0	98	100	90	100
Durham Ferry	5/9/05	83	10	100	12	100	0	100	100	94	100
Dos Reis	5/10/05	87	7	100	6	100	0	100	100	76	100
Jersey Point	5/13/05	85	7	100	2	100	0	100	100	74	100
* % correct tag code of those that retained tags.											

Table A-3. Salmon smolt condition 48-hours post release

Release Site	Examination Date	Mean Fork Length (mm)	Mean Weight (g)	Vigor (%)	Mean Scale Loss (%)	Normal Body Color (%)	Fin Hemorrhaging (%)	Normal Eye Quality (%)	Normal Gill Color (%)	Complete Adclip (%)
Durham Ferry	5/4/05	84	7	100	9	96	0	100	100	74
Dos Reis	5/5/05	85	7	100	8	98	0	96	100	78
Jersey Point	5/8/05	86	7	100	7	98	2	98	100	84
Durham Ferry	5/11/05	84	6	100	7	100	0	98	100	68
Dos Reis	5/12/05	85	7	100	3	100	0	98	98	76
Jersey Point	5/15/05	87	7	100	3	100	0	100	100	70

Figure A-11. Antioch/Durham Ferry 1

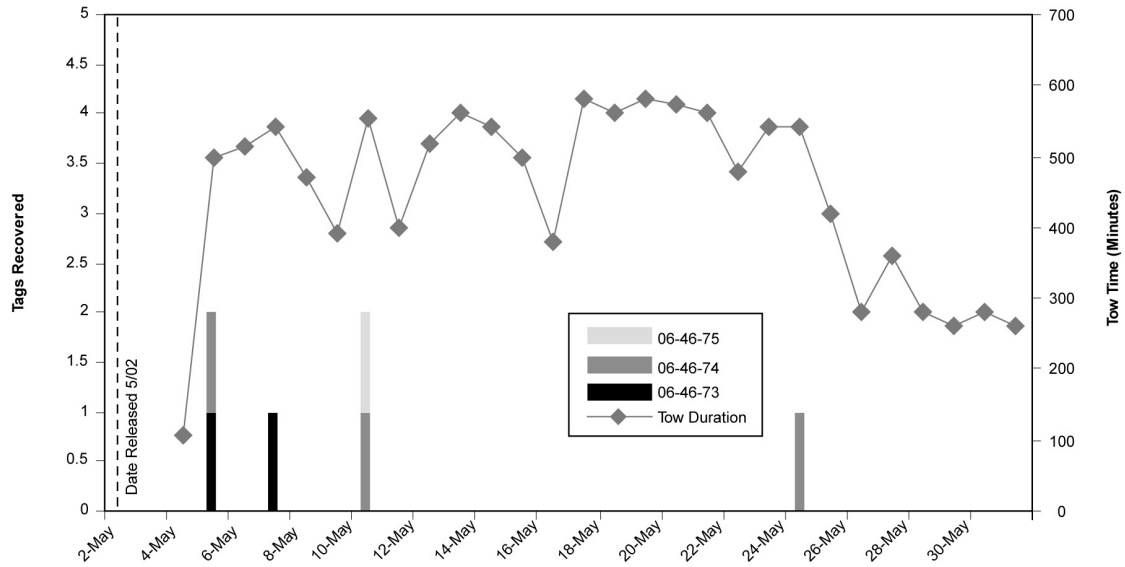


Figure A-12. Antioch/Dos Reis 1

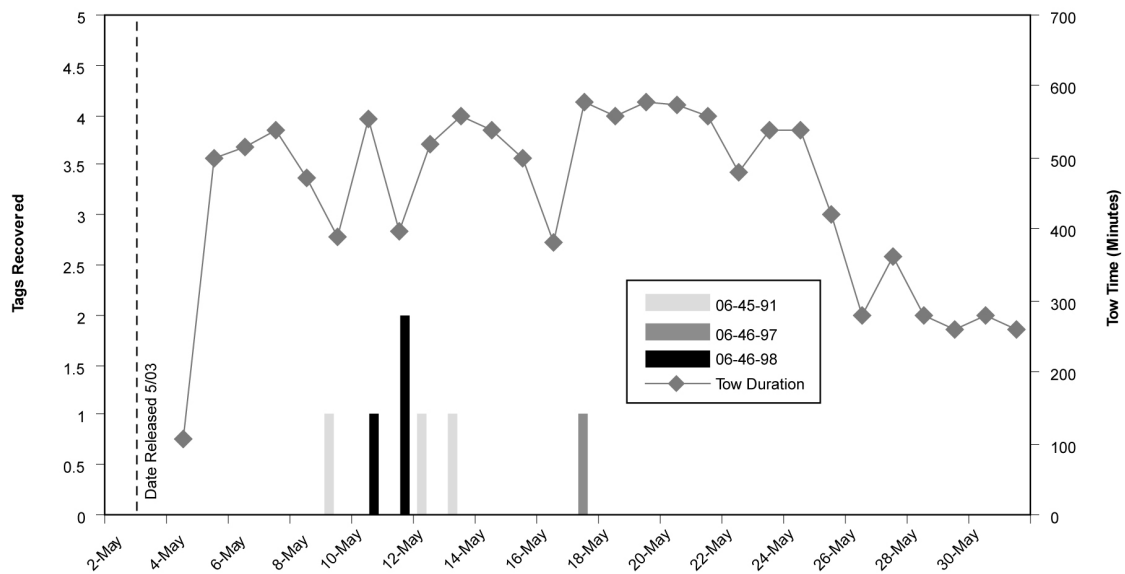


Figure A-13. Antioch/Jersey Point 1

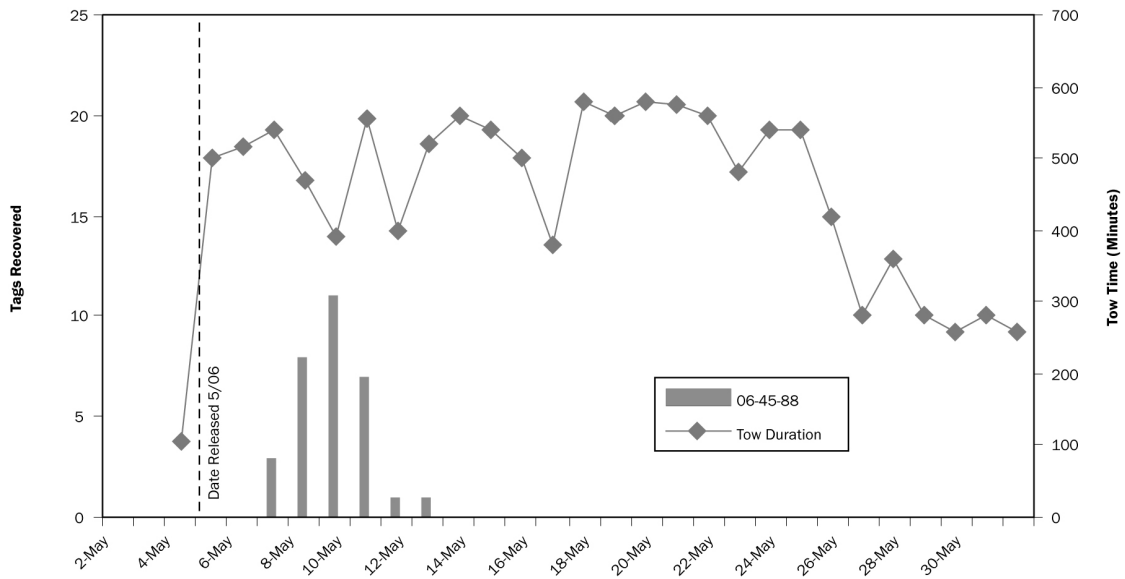


Figure A-14. Chipps Island/Durham Ferry 1

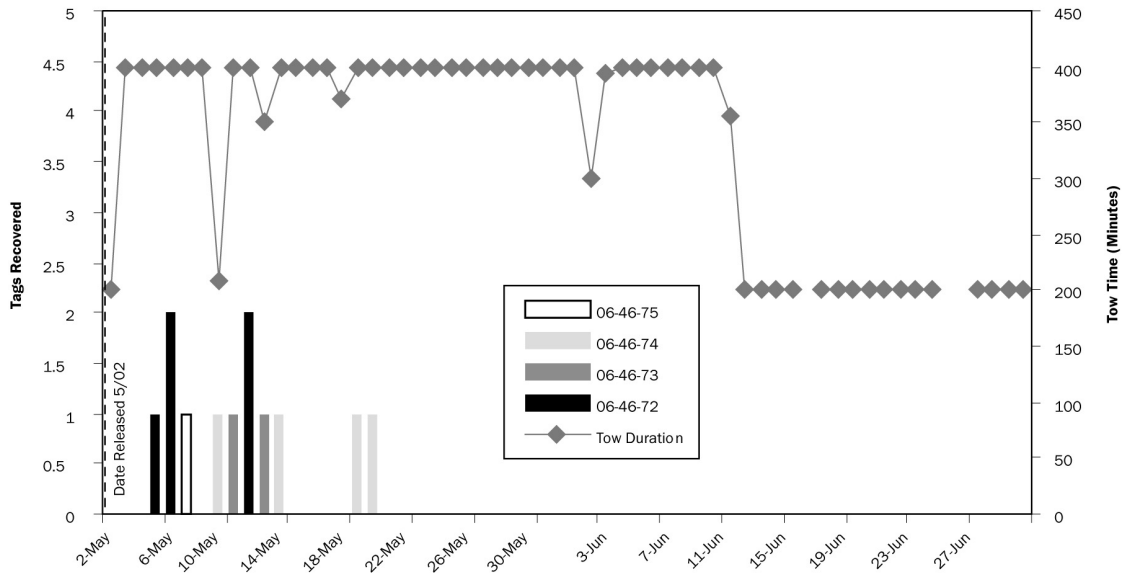


Figure A-15. Chipps Island/Dos Reis 1

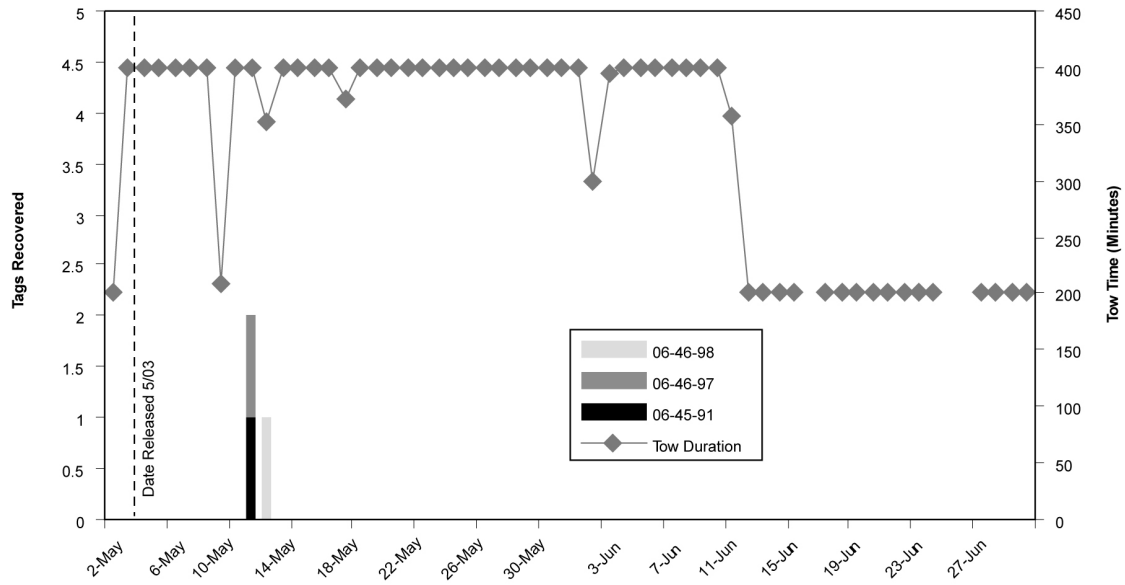


Figure A-16. Chipps Island/Jersey Point 1

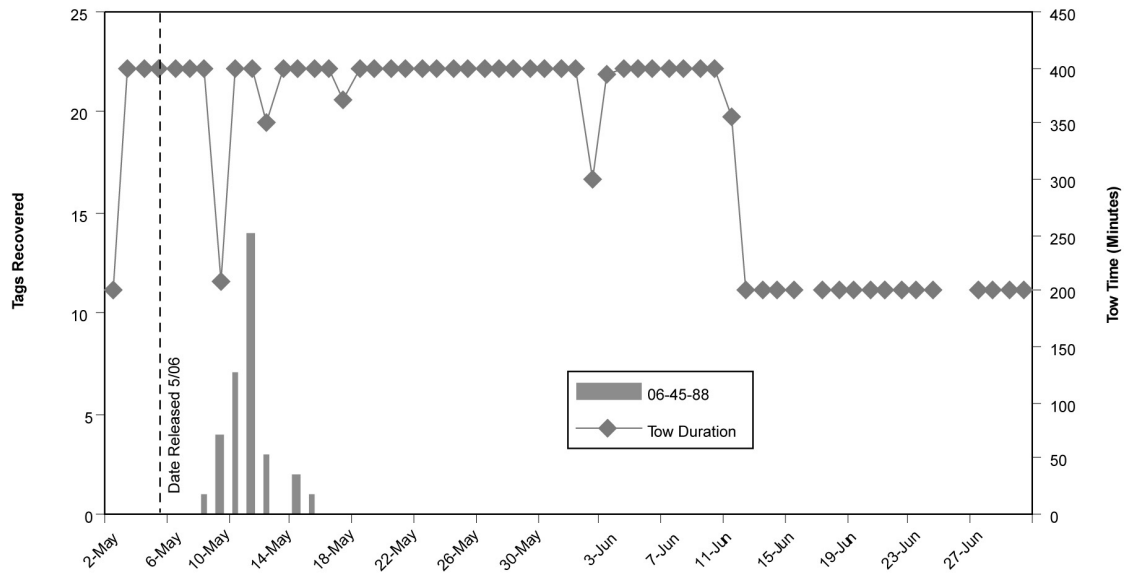


Figure A-17. Antioch/Durham Ferry 2

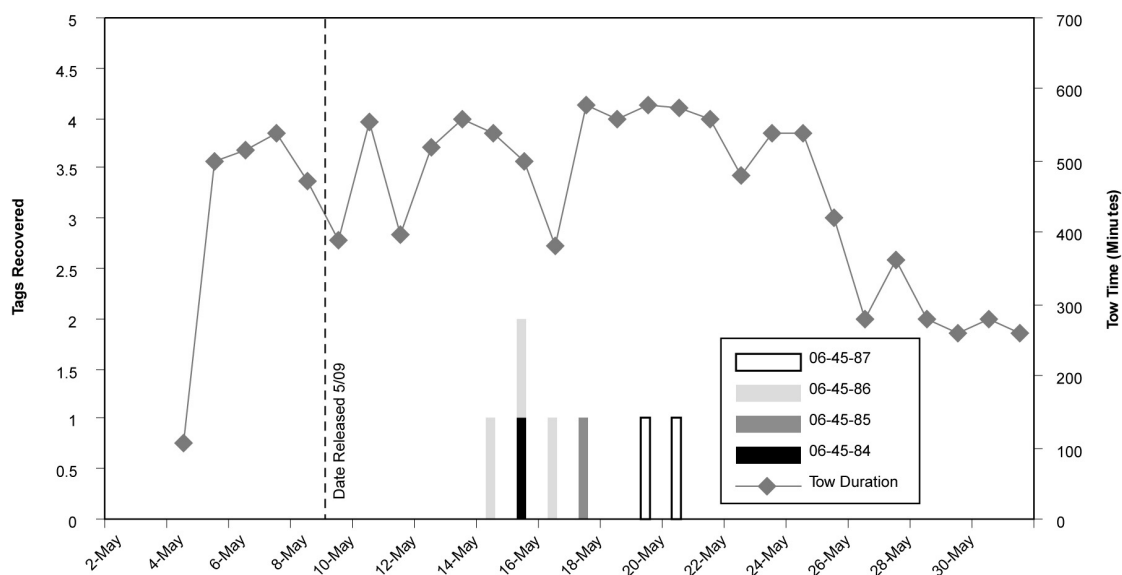


Figure A-18. Antioch/Dos Reis 2

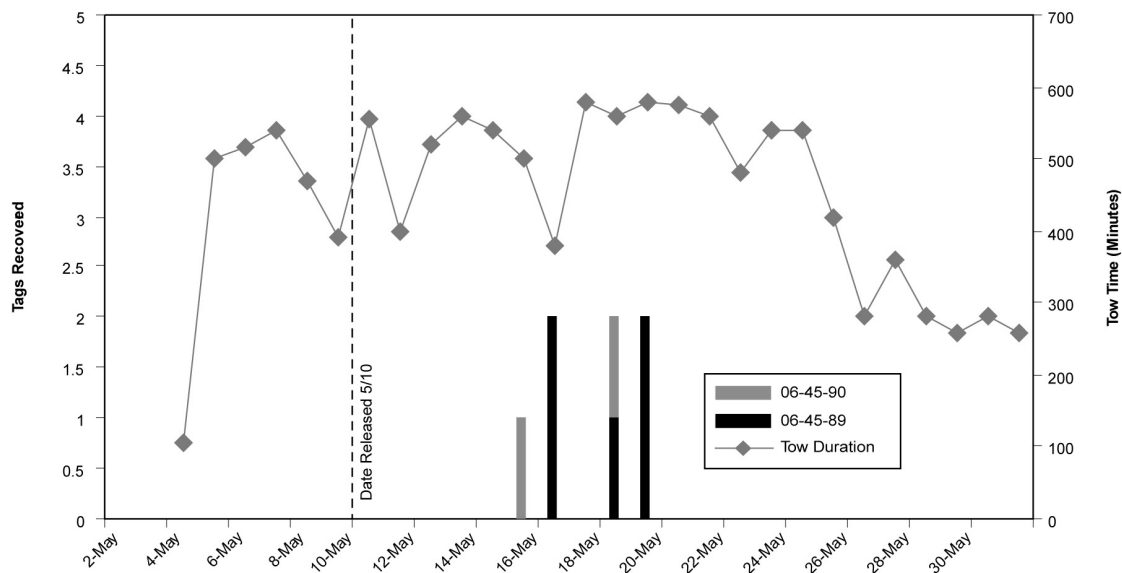


Figure A-19. Antioch/Jersey Point 2

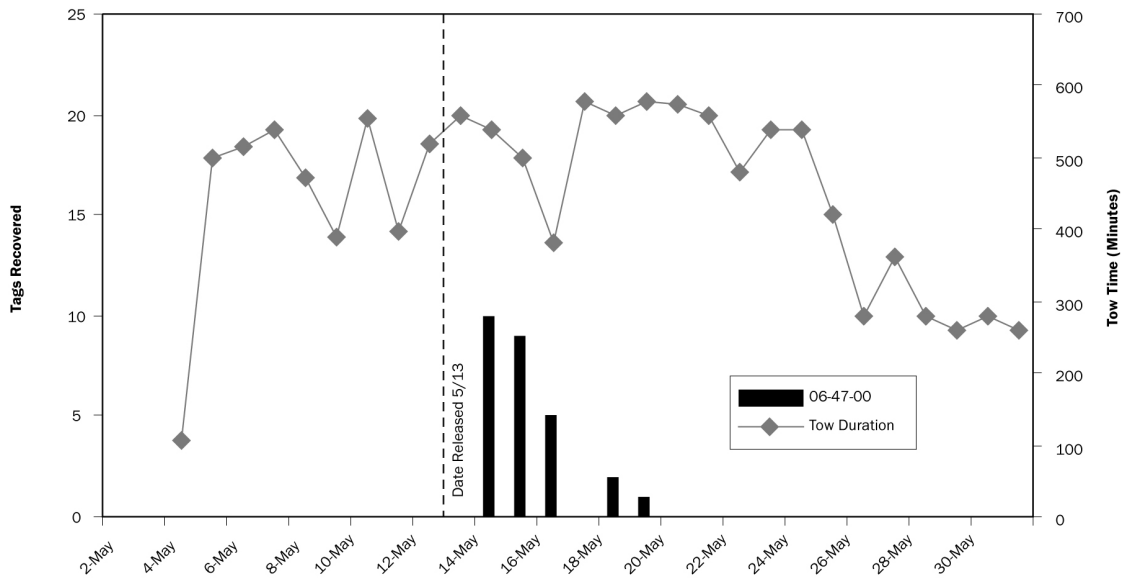


Figure A-20. Chipps Island/Durham Ferry 2

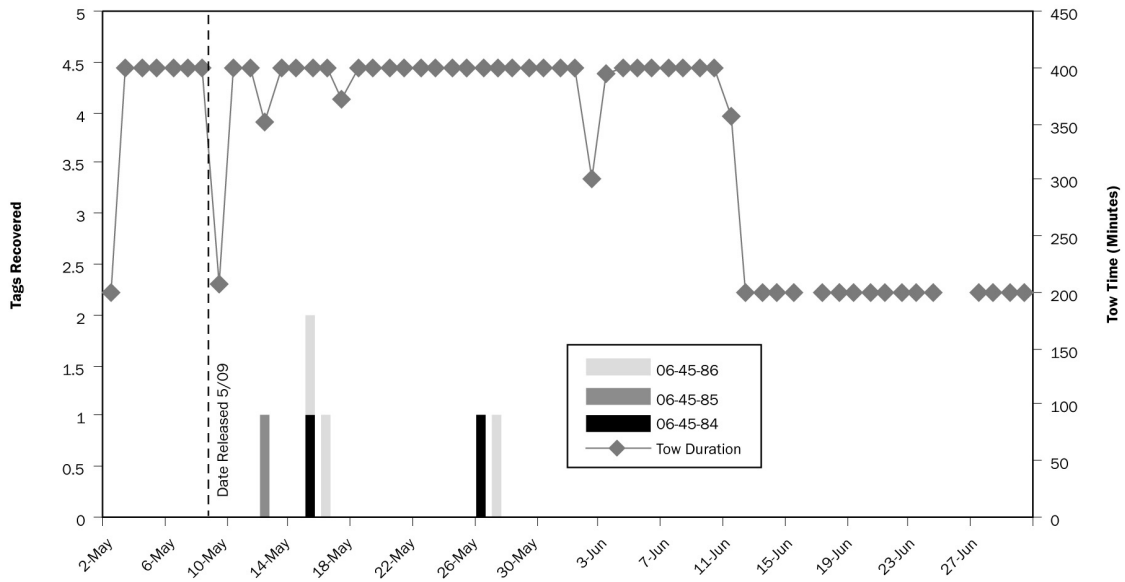


Figure A-21. Chipps Island/Dos Reis 2

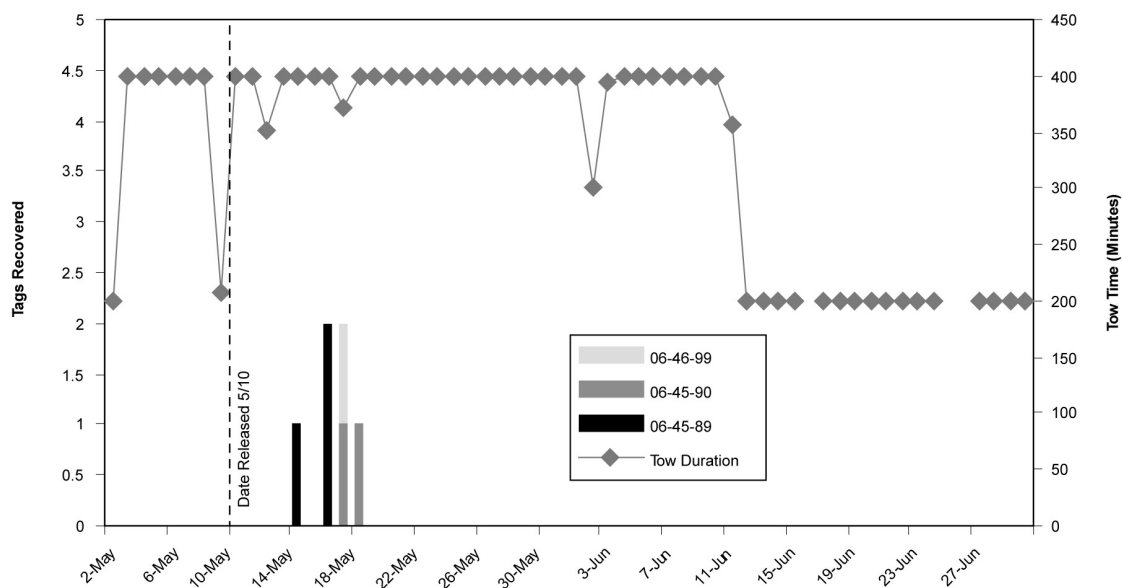
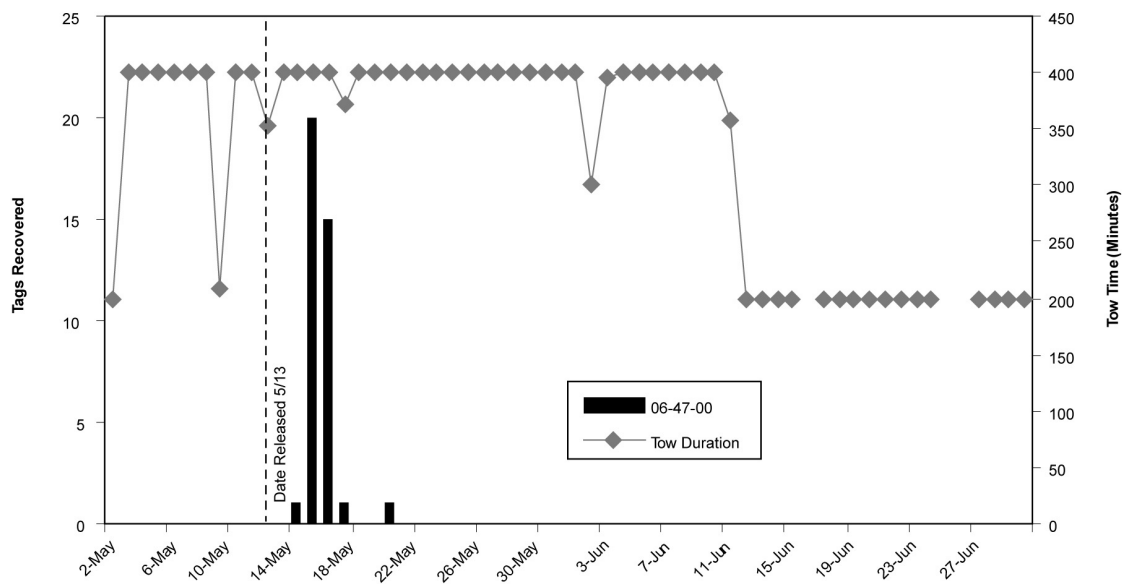


Figure A-22. Chipps Island/Jersey Point 2



Appendix B. Stage and Flow Data

This appendix consists of the stage and flow data that is presented graphically in this report via box plots. The values are derived from 15-minute simulated stage and flow over each of the 20 time periods in 2005 presented in Table B-3.

Figure B-1. Locations stage and flow data presented for the simulation of 2005 hydrodynamics

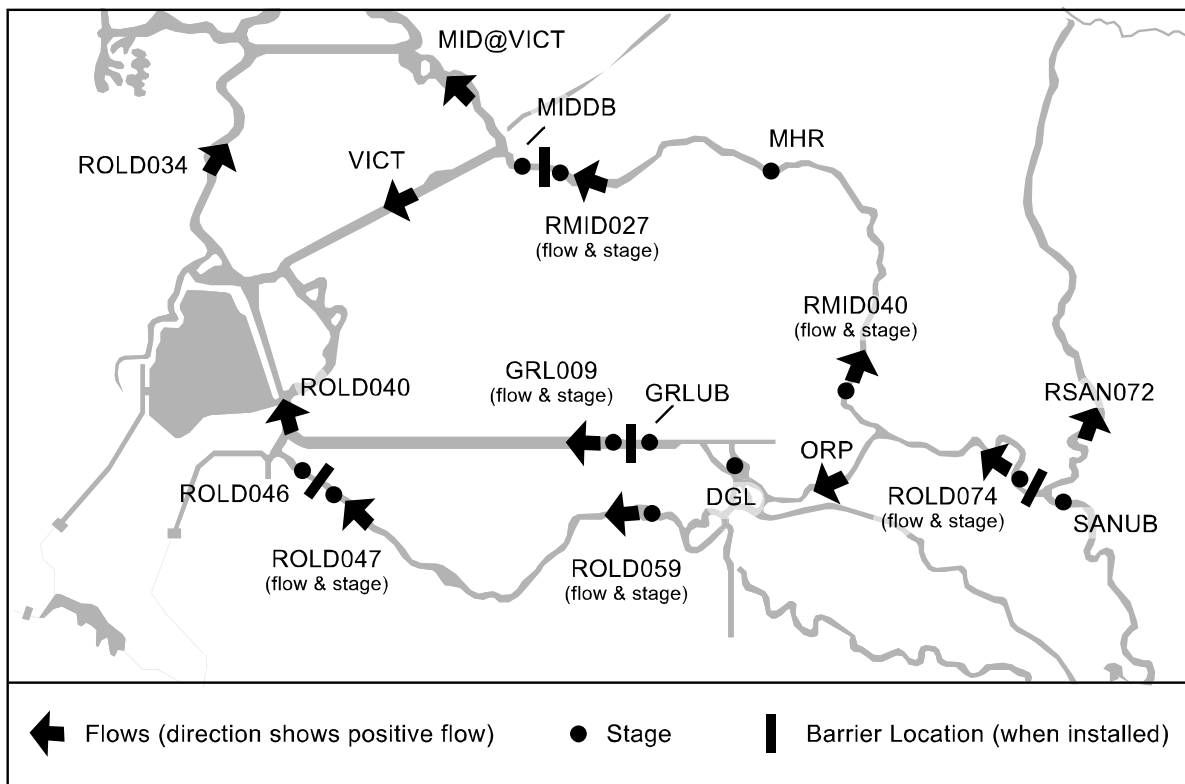


Table B-1. Distribution of stages (feet) by study period in 2005

		GRL009					GRLUB					DGL				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-0.35	0.54	1.27	1.83	5.39	-0.35	0.54	1.27	1.83	5.39	-0.16	0.68	1.42	1.97	5.49
Feb	1 - 28	-0.23	0.75	1.47	2.04	4.41	-0.23	0.75	1.47	2.04	4.41	-0.04	0.88	1.62	2.20	4.52
Mar	1 - 15	0.31	0.99	1.74	2.40	4.00	0.31	0.99	1.74	2.40	4.00	0.56	1.20	1.93	2.57	4.10
	16 - 31	0.03	1.34	1.99	2.65	4.56	0.03	1.34	1.99	2.65	4.56	0.28	1.52	2.22	2.90	4.71
Apr	1 - 17	0.20	1.47	1.99	2.46	3.99	0.20	1.47	1.99	2.46	3.99	0.63	1.80	2.33	2.81	4.23
	18 - 30	0.24	1.16	1.87	2.48	4.52	0.24	1.16	1.87	2.48	4.52	0.54	1.40	2.07	2.63	4.61
May	1 - 12	0.27	1.49	2.20	2.86	4.73	0.27	1.49	2.20	2.86	4.73	0.58	1.71	2.39	3.00	4.84
	12 - 19	0.49	1.48	2.00	2.53	3.72	0.49	1.48	2.00	2.53	3.72	0.85	1.74	2.21	2.69	3.82
	20 - 25	1.24	2.15	2.85	3.36	5.25	1.24	2.15	2.85	3.36	5.25	1.59	2.51	3.14	3.63	5.42
	26 - 31	1.66	2.44	3.00	3.42	5.31	1.66	2.44	3.00	3.42	5.31	2.27	2.90	3.39	3.73	5.49
Jun	1 - 12	0.62	2.06	2.54	2.99	4.68	0.62	2.06	2.54	2.99	4.68	1.17	2.63	3.01	3.41	4.86
	12 - 30	-0.11	0.78	1.41	1.81	4.48	-0.11	0.78	1.41	1.81	4.48	0.18	1.04	1.64	2.04	4.56
Jul	1 - 12	-0.40	0.65	1.28	1.72	3.77	-0.12	0.65	1.28	1.72	3.77	0.21	0.86	1.47	1.92	3.84
	12 - 31	-1.51	-0.14	0.73	1.36	4.38	1.40	2.34	2.56	2.70	4.04	1.41	2.36	2.58	2.72	4.12
Aug	1 - 31	-1.31	-0.12	0.65	1.09	4.07	1.81	2.09	2.33	2.49	3.80	1.82	2.10	2.34	2.50	3.86
Sep	1 - 28	-1.48	-0.08	0.63	1.01	3.77	1.82	2.04	2.25	2.41	3.52	1.82	2.05	2.27	2.42	3.58
Oct	1 - 31	-1.51	-0.29	0.43	0.86	3.60	1.53	1.74	1.92	2.03	2.92	1.53	1.74	1.93	2.03	2.97
Nov	1 - 7	-1.57	-0.33	0.56	1.15	3.59	1.48	1.83	2.05	2.25	3.05	1.48	1.84	2.06	2.26	3.11
	14 - 30	-0.87	-0.13	0.59	1.09	3.17	-0.87	-0.13	0.59	1.10	3.17	-0.76	-0.06	0.66	1.18	3.25
Dec	1 - 31	-0.95	0.18	1.19	1.99	7.74	-0.95	0.18	1.19	1.99	7.74	-0.83	0.27	1.29	2.10	7.86

Table B-1 – cont. Distribution of stages (feet) by study period in 2005

		ROLD046					ROLD047					ROLD059				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-1.01	0.15	0.92	1.51	5.16	-1.01	0.15	0.92	1.51	5.16	-0.46	0.46	1.20	1.79	5.48
Feb	1 - 28	-0.78	0.36	1.13	1.71	4.24	-0.78	0.36	1.13	1.71	4.24	-0.34	0.69	1.42	1.98	4.51
Mar	1 - 15	-0.44	0.49	1.30	2.05	3.79	-0.44	0.49	1.30	2.05	3.79	0.12	0.90	1.66	2.34	4.05
	16 - 31	-0.61	0.81	1.52	2.19	4.29	-0.61	0.81	1.52	2.19	4.29	-0.09	1.24	1.93	2.59	4.63
Apr	1 - 17	-0.86	0.65	1.30	1.85	3.73	-0.86	0.65	1.30	1.85	3.73	-0.03	1.29	1.86	2.36	4.02
	18 - 30	-0.62	0.65	1.44	2.15	4.34	-0.62	0.65	1.44	2.15	4.34	0.10	1.08	1.80	2.43	4.57
May	1 - 12	-0.51	1.02	1.79	2.57	4.50	-0.51	1.02	1.79	2.57	4.50	0.12	1.41	2.13	2.81	4.78
	12 - 19	-0.38	0.95	1.57	2.23	3.57	-0.38	0.95	1.57	2.23	3.57	0.29	1.38	1.93	2.50	3.76
	20 - 25	0.45	1.52	2.30	2.95	4.99	0.45	1.52	2.30	2.95	4.99	1.07	2.04	2.77	3.32	5.33
	26 - 31	0.07	1.52	2.26	2.93	5.05	0.25	1.72	2.37	2.97	5.05	1.39	2.41	2.93	3.37	5.39
Jun	1 - 12	-1.12	0.68	1.44	2.17	4.38	0.91	2.29	2.59	2.92	4.08	0.98	2.42	2.75	3.10	4.48
	12 - 30	-1.18	0.12	0.81	1.31	4.29	0.01	0.79	1.33	1.70	4.06	0.08	0.84	1.39	1.76	4.33
Jul	1 - 12	-1.31	0.07	0.75	1.26	3.59	0.24	0.73	1.28	1.75	2.85	0.27	0.75	1.30	1.73	3.16
	12 - 31	-1.59	-0.34	0.54	1.18	4.26	0.88	2.31	2.50	2.64	3.58	0.97	2.31	2.51	2.65	3.89
Aug	1 - 31	-1.42	-0.29	0.49	0.95	3.95	1.78	2.07	2.30	2.46	3.54	1.79	2.07	2.30	2.45	3.75
Sep	1 - 28	-1.58	-0.23	0.48	0.88	3.67	1.78	2.03	2.24	2.39	3.27	1.80	2.03	2.24	2.38	3.46
Oct	1 - 31	-1.62	-0.43	0.31	0.76	3.53	1.51	1.73	1.92	2.04	2.84	1.52	1.73	1.92	2.03	2.92
Nov	1 - 7	-1.60	-0.52	0.44	1.04	3.51	1.46	1.84	2.06	2.26	2.97	1.47	1.83	2.05	2.24	3.07
	14 - 30	-1.26	-0.39	0.36	0.86	3.02	-1.26	-0.39	0.36	0.86	3.02	-0.93	-0.21	0.53	1.03	3.21
Dec	1 - 31	-1.34	-0.08	0.93	1.74	7.46	-1.34	-0.08	0.93	1.74	7.46	-1.01	0.10	1.13	1.89	7.80

Table B-1 – cont. Distribution of stages (feet) by study period in 2005

		MIDDB					RMID027					MHR				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-1.08	0.45	1.26	1.94	5.24	-1.05	0.48	1.28	1.96	5.27	0.06	1.04	1.73	2.27	5.41
Feb	1 - 28	-0.84	0.52	1.33	2.04	4.18	-0.81	0.55	1.35	2.05	4.21	0.14	1.14	1.84	2.44	4.38
Mar	1 - 15	-0.59	0.58	1.40	2.12	3.75	-0.53	0.63	1.44	2.14	3.78	0.88	1.46	2.08	2.60	4.01
	16 - 31	-0.78	0.74	1.53	2.24	4.09	-0.75	0.80	1.57	2.27	4.15	0.44	1.77	2.39	3.01	4.53
Apr	1 - 17	-1.20	0.50	1.22	1.91	3.55	-1.13	0.57	1.28	1.96	3.60	0.92	2.01	2.55	3.05	4.12
	18 - 30	-0.87	0.57	1.38	2.13	4.21	-0.83	0.60	1.41	2.16	4.25	0.71	1.56	2.13	2.56	4.46
May	1 - 12	-0.75	0.85	1.66	2.48	4.35	-0.71	0.88	1.69	2.52	4.39	0.69	1.77	2.36	2.87	4.66
	12 - 19	-0.69	0.75	1.44	2.24	3.40	0.88	1.34	1.83	2.29	3.43	1.41	1.96	2.32	2.66	3.65
	20 - 25	0.14	1.25	2.09	2.81	4.81	1.27	1.74	2.45	2.95	4.84	1.75	2.79	3.27	3.66	5.22
	26 - 31	-0.29	1.21	2.02	2.81	4.87	1.45	1.82	2.50	2.99	4.90	2.89	3.30	3.65	3.87	5.28
Jun	1 - 12	-1.12	0.72	1.48	2.27	4.24	0.74	1.56	2.08	2.48	4.29	1.55	2.89	3.22	3.55	4.77
	12 - 30	-1.15	0.30	1.09	1.73	4.37	0.14	0.92	1.45	1.80	4.34	0.31	1.24	1.76	2.13	4.54
Jul	1 - 12	-1.08	0.45	1.15	1.74	3.77	0.39	1.13	1.55	1.80	3.66	0.50	1.16	1.65	1.99	3.79
	12 - 31	-1.32	0.16	1.05	1.72	4.32	1.05	1.25	1.70	1.91	4.20	1.10	1.34	1.81	2.06	4.24
Aug	1 - 31	-1.11	0.20	1.01	1.63	4.04	1.15	1.28	1.67	1.78	3.99	1.20	1.38	1.77	1.95	3.93
Sep	1 - 28	-1.30	0.23	1.00	1.61	3.75	1.22	1.32	1.67	1.78	3.69	1.29	1.43	1.78	1.95	3.67
Oct	1 - 31	-1.34	0.02	0.81	1.47	3.64	1.14	1.25	1.54	1.62	3.52	1.17	1.31	1.58	1.69	3.26
Nov	1 - 7	-1.31	0.12	0.90	1.54	3.63	1.13	1.26	1.61	1.68	3.52	1.15	1.34	1.66	1.81	3.34
	14 - 30	-1.23	-0.02	0.70	1.34	3.25	-1.23	-0.03	0.71	1.34	3.26	-0.76	0.12	0.79	1.31	3.23
Dec	1 - 31	-1.32	0.29	1.31	2.09	7.37	-1.31	0.31	1.32	2.09	7.42	-0.83	0.47	1.48	2.19	7.72

Table B-1 – cont. Distribution of stages (feet) by study period in 2005

		RMID040					ROLD074					SANUB				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	0.53	1.45	2.17	2.75	5.55	1.68	3.01	3.70	4.40	6.11	1.68	3.01	3.70	4.40	6.11
Feb	1 - 28	0.60	1.46	2.34	3.11	4.91	1.99	2.75	3.86	5.04	6.41	1.99	2.75	3.86	5.04	6.41
Mar	1 - 15	1.80	2.30	2.83	3.26	4.47	3.95	4.47	4.75	4.93	5.74	3.95	4.47	4.75	4.93	5.74
	16 - 31	1.41	2.41	3.39	4.47	5.67	3.58	4.14	5.61	7.31	8.57	3.58	4.14	5.61	7.31	8.57
Apr	1 - 17	2.49	3.39	4.14	4.89	5.71	5.36	6.17	7.10	8.26	8.62	5.36	6.17	7.10	8.26	8.62
	18 - 30	1.84	2.65	3.05	3.36	4.82	4.25	4.90	5.15	5.42	5.70	4.25	4.90	5.15	5.42	5.70
May	1 - 12	1.95	2.79	3.27	3.67	5.14	4.43	4.99	5.31	5.62	6.34	4.43	4.99	5.31	5.62	6.34
	12 - 19	2.56	3.04	3.32	3.61	4.36	5.26	5.51	5.63	5.74	6.04	5.26	5.51	5.63	5.74	6.04
	20 - 25	2.95	4.22	4.68	5.09	6.33	5.68	7.01	7.48	8.06	8.63	5.68	7.01	7.48	8.06	8.63
	26 - 31	4.80	5.21	5.42	5.58	6.44	8.21	8.42	8.63	8.80	9.05	8.21	8.42	8.63	8.80	9.05
Jun	1 - 12	3.26	4.75	5.16	5.60	6.37	6.41	7.92	8.48	9.08	9.39	6.41	7.92	8.48	9.08	9.39
	12 - 30	1.20	2.16	2.66	3.19	4.84	3.42	4.28	4.86	5.43	6.65	3.42	4.28	4.86	5.43	6.65
Jul	1 - 12	1.20	1.75	2.24	2.61	4.13	3.10	3.71	4.11	4.50	5.28	3.10	3.71	4.11	4.50	5.28
	12 - 31	1.53	2.24	2.54	2.71	4.30	2.50	3.02	3.34	3.57	4.86	2.50	3.02	3.34	3.57	4.86
Aug	1 - 31	1.69	1.98	2.28	2.45	3.97	1.94	2.44	2.80	3.08	4.18	1.94	2.44	2.80	3.08	4.18
Sep	1 - 28	1.71	1.95	2.21	2.35	3.70	1.90	2.30	2.63	2.88	3.88	1.90	2.30	2.63	2.88	3.88
Oct	1 - 31	1.43	1.64	1.85	1.96	3.08	1.58	1.82	2.05	2.20	3.18	1.80	2.63	2.93	3.20	4.21
Nov	1 - 7	1.39	1.73	1.98	2.16	3.24	1.51	1.99	2.19	2.38	3.31	1.58	2.45	2.78	3.09	4.10
	14 - 30	-0.49	0.29	0.94	1.42	3.32	0.49	1.22	1.71	2.10	3.33	0.49	1.22	1.71	2.10	3.33
Dec	1 - 31	-0.50	0.68	1.74	2.44	8.13	0.64	1.65	2.82	3.24	9.11	0.64	1.65	2.82	3.24	9.11

Table B-2. Distribution of flows (cfs) by study period in 2005

	ROLD040					ROLD047					ROLD059				
	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan 1 - 31	-16596	-4146	-1235	2828	10738	-3212	-429	470	1488	3854	-727	62	419	727	1592
Feb 1 - 28	-14014	-4302	-947	3282	13674	-2452	-549	464	1580	3718	-585	62	434	798	1294
Mar 1 - 15	-11628	-4727	-754	4489	9764	-2214	-703	553	1905	3175	-440	87	534	919	1301
16 - 31	-11335	-2447	1826	6390	14115	-2689	-611	648	1942	3554	-516	147	645	1020	1715
Apr 1 - 17	-9581.8	292.83	3546	7037	14244	-2475	-135	884	1887	3452	-491	601	887	1262	1707
18 - 30	-10136	-2699	1698	6607	10811	-2425	-898	512	1828	2682	-509	16	540	951	1156
May 1 - 12	-10330	-3512	2349	7432	12340	-2790	-1224	489	1913	2733	-543	-77	553	1001	1280
12 - 19	-7426.4	-966.4	3270	7398	8917	-2095	-716	574	1744	2137	-482	112	614	1000	1153
20 - 25	-8434.8	-282.5	4529	9055	14285	-2660	-795	814	2140	3233	-459	322	900	1375	1739
26 - 31	-8090.8	1906.7	5873	9837	14998	-2647	-62	1086	2249	3673	-443	753	1136	1524	1905
Jun 1 - 12	-8892.4	241.37	2866	6262	13104	-1232	464	661	1048	1746	254	615	765	901	1530
12 - 30	-13653	-3171	-954	2471	11790	-1449	-73	251	614	1782	-106	204	357	462	1250
Jul 1 - 12	-14199	-3902	-1640	2092	10094	-1388	-204	22	309	966	-571	-11	168	339	1177
12 - 31	-16172	-5710	-3255	-943	11886	-1545	48	92	210	959	-140	155	243	282	1097
Aug 1 - 31	-15007	-5483	-3555	-1310	12230	-1410	1	23	110	876	-119	18	118	173	938
Sep 1 - 28	-14847	-5443	-3557	-1418	10060	-1102	0	10	84	691	-194	-68	56	143	795
Oct 1 - 31	-13677	-5644	-3942	-2175	8708	-1290	0	-45	0	373	-287	-77	-17	23	511
Nov 1 - 7	-13462	-5671	-3903	-1696	6141	-1146	0	-42	34	460	-204	-112	-28	8	509
14 - 30	-14337	-6283	-2951	1482	9267	-2450	-700	172	1241	2859	-643	-129	185	486	1028
Dec 1 - 31	-17803	-5801	-2308	1848	16259	-3818	-693	289	1328	5268	-880	-87	303	582	2364

Table B-2 cont. Distribution of flows (cfs) by study period in 2005

	MID at VICT					RMID027					RMID040				
	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan 1 - 31	-16541	-9530	-3740	2093	7491	-1944	-483	147	734	2286	-91	74	123	172	388
Feb 1 - 28	-13942	-8732	-2545	3522	9020	-1392	-497	161	785	2017	-70	86	158	248	447
Mar 1 - 15	-12406	-8346	-1570	5978	8215	-1212	-485	228	924	1749	162	204	232	253	369
16 - 31	-12942	-7686	-965	6375	9271	-1289	-396	313	941	2043	57	181	331	507	722
Apr 1 - 17	-12000	-7109	-612	5813	8958	-1204	-88	464	956	1918	268	362	483	618	728
18 - 30	-12460	-7445	-231	6806	9414	-1368	-481	242	883	1332	185	249	274	301	369
May 1 - 12	-12853	-7323	387	7385	9810	-1532	-599	241	940	1731	204	262	297	325	452
12 - 19	-9474	-5594	576	6619	8467	-943	-161	274	633	1005	251	300	320	344	398
20 - 25	-11910	-6546	1149	7703	10554	-1104	-155	464	938	1436	299	463	538	610	755
26 - 31	-11423	-6287	1236	7541	10611	-879	205	640	1043	1764	594	657	690	724	781
Jun 1 - 12	-13101	-7279	-833	5763	8980	-1108	261	561	930	1866	366	577	674	763	853
12 - 30	-14268	-8312	-2970	2485	8258	-1448	-230	134	479	1712	127	190	247	293	437
Jul 1 - 12	-14875	-9589	-3868	1871	5856	-1483	-363	27	381	1386	77	151	182	210	298
12 - 31	-16836	-9644	-4671	49	6936	-1712	-97	51	281	1501	-49	200	213	236	286
Aug 1 - 31	-15477	-9923	-4632	372	7279	-1552	-80	67	268	1352	-129	155	163	188	222
Sep 1 - 28	-14257	-10151	-4588	637	7014	-1335	-55	88	285	1236	-136	142	145	166	205
Oct 1 - 31	-14325	-9808	-4415	623	6713	-1421	-13	41	211	1027	-174	95	98	132	171
Nov 1 - 7	-13748	-9867	-4075	2233	7008	-1323	-17	49	236	957	-138	99	108	145	169
14 - 30	-13945	-8837	-3254	2501	7213	-1418	-576	-14	524	1579	-98	25	38	53	130
Dec 1 - 31	-17767	-9602	-3926	1726	9309	-2002	-602	29	618	2912	-111	30	95	105	806

Table B-2 cont. Distribution of flows (cfs) by study period in 2005

		GRL009					ORP					ROLD074				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-4147	1426	2483	3959	7434	1261	2296	2796	3149	4502	1016	2367	2905	3418	4929
Feb	1 - 28	-3166	1236	2484	4136	6706	1225	2144	2846	3778	4682	1226	2171	2997	3972	5099
Mar	1 - 15	-1875	1887	3030	4830	6441	2563	3276	3511	3784	4115	2968	3501	3739	3988	4350
	16 - 31	-2298	2097	3643	5168	7739	2045	3082	4291	5761	7073	2496	3220	4636	6245	7697
Apr	1 - 17	-1063	3879	4867	5999	7623	4047	4925	5745	6839	7100	4541	5244	6220	7483	7746
	18 - 30	-2169	1966	3234	4883	5450	2551	3527	3817	4174	4482	3057	3748	4092	4460	4884
May	1 - 12	-2502	1202	3168	4905	5850	2882	3562	3831	4096	4510	3462	3915	4149	4388	4808
	12 - 19	-1141	2373	3622	4924	5378	3652	4112	4256	4417	4657	4270	4506	4580	4661	4931
	20 - 25	-835	3425	4724	6216	7231	3851	5300	5814	6385	6803	4748	5917	6394	6996	7359
	26 - 31	-215	4972	5840	7038	7985	5914	6789	7021	7349	7635	6996	7414	7726	8075	8413
Jun	1 - 12	1016	5263	6130	7486	8506	5024	6514	7014	7616	7749	5665	7135	7698	8369	8668
	12 - 30	-3323	2370	3236	4869	7480	2304	3180	3738	4084	5399	2839	3406	4000	4390	5743
Jul	1 - 12	-3525	1748	2743	4666	5969	2032	2923	3110	3327	3778	2463	3056	3318	3579	4283
	12 - 31	-2308	1022	1127	1518	2870	977	1377	1596	1787	2763	1105	1535	1841	2041	3567
Aug	1 - 31	-2215	779	885	1213	2786	161	839	1133	1406	2247	201	937	1313	1592	2904
Sep	1 - 28	-1805	786	831	1111	2445	230	627	949	1264	2154	267	700	1105	1437	2539
Oct	1 - 31	-2404	437	468	758	1827	155	328	494	634	1262	170	434	603	759	1307
Nov	1 - 7	-2109	453	525	913	1750	-56	418	529	644	1162	2	506	650	759	1312
	14 - 30	-3639	-111	1183	2900	5186	443	1268	1388	1594	1820	192	1145	1436	1794	2400
Dec	1 - 31	-4287	305	1718	3302	9516	-246	1496	2078	2321	6035	-457	1311	2197	2436	6741

Table B-2 cont. Distribution of flows (cfs) by study period in 2005

		VICT					ROLD034					RSAN072				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-2663	939	3222	5728	9394	-18196	-11106	-5716	-1273	6734	-2107	1465	2124	3056	4583
Feb	1 - 28	-3560	-775	2166	4736	7961	-15312	-9342	-3712	2236	8760	-1440	1636	2384	3391	4850
Mar	1 - 15	-2784	-1728	1542	3907	7600	-13926	-8099	-2246	5127	7352	1748	2824	3299	3731	4297
	16 - 31	-3746	-2283	1016	3436	7590	-14745	-7221	-1272	6128	9224	1261	2812	4066	5597	7067
Apr	1 - 17	-3615	-2193	865	3635	6770	-12901	-6983	-834	5546	8942	3707	4614	5529	6518	7094
	18 - 30	-3677	-2594	304	2599	6797	-12634	-6040	-56	6679	9089	1864	3353	3694	4154	4499
May	1 - 12	-4151	-2873	-217	2288	6553	-13259	-5562	994	7387	9926	2369	3323	3767	4170	4735
	12 - 19	-3694	-2903	-363	1868	7021	-12449	-3750	1332	7019	8760	3131	3841	4149	4459	4699
	20 - 25	-4679	-3372	-714	1791	6093	-12012	-3844	2218	8054	10935	3434	5106	5688	6285	6911
	26 - 31	-4605	-3152	-635	1590	6857	-11653	-3189	2324	7861	11017	5607	6571	6853	7157	7610
Jun	1 - 12	-2903	-1987	1008	2999	7572	-13881	-5770	-938	5325	7723	4630	6273	6804	7476	7780
	12 - 30	-2538	-82	2408	4562	8044	-15643	-8904	-4189	465	7262	1008	2849	3427	4073	5166
Jul	1 - 12	-1994	1091	3122	5689	8825	-17141	-10969	-5693	-1599	5075	526	2150	2702	3308	3885
	12 - 31	-1981	2052	3675	5321	9777	-19131	-10120	-6841	-3561	4926	-1542	1358	1879	2683	3093
Aug	1 - 31	-2131	2002	3756	5899	9281	-17406	-11170	-6908	-3378	4994	-2033	656	1338	2289	2805
Sep	1 - 28	-2018	1834	3762	6085	8655	-16121	-11506	-6878	-2977	4727	-1857	261	1125	2152	2535
Oct	1 - 31	-1628	1729	3589	5715	8125	-15447	-10972	-6625	-2916	4448	-1180	1131	1713	2470	2814
Nov	1 - 7	-1554	662	3220	5667	7895	-15508	-10927	-5873	-1030	4657	-1438	812	1454	2329	2688
	14 - 30	-2329	-12	2638	5018	7667	-15513	-10167	-4881	477	6211	-2207	-851	471	1731	2251
Dec	1 - 31	-3061	1034	3190	5592	10597	-19568	-11221	-5824	-1266	8287	-2851	-306	1178	2206	6257

